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Part 1

EXPERIMENTAL M..GNESIUM ALLOYS

Part 1 Further Development of Pellet Fabricated Magnesium Alloys.

Edited by

H. A. Johnson, 1st Lt., USAF

Materials Laboratory

JUNE 1954

WRIGHT AIR DEVELOPMENT CENTER

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FOREWORD

This report was prepared by The Dow Chemical Company under USAF Contract No. AF(600)19147. The contract was initiated under Research and Development Order No. R615-15 BA, "New Experimental Alloys by the Powder Metallurgy Process", and was administered under the direction of the Materials Laboratory, Directorate of Research, Wright Air Development Center, with Lt H. A. Johnson acting as project engineer.

ABSTRACT

The effect of melt and Mg-Al pellet additions on the properties of Mg-Zn-Zr pellet and/or ingot fabrications was investigated in an attempt to develop higher strength sheet and extrusion alloys. The best combination of properties of Mg-Zn-Zr + Mg-Al pellet extrusions is obtained with ZK60; addition of Mg-Al decreases the sensitivity of the extrusion to annealing but does not improve the overall properties of the base alloy. Certain melt additions, however, do result in significant improvements in the properties of Mg-Zn-Zr. In extrusions, QZ66 containing 2% MM offers much higher strength, particularly CYS, than ZK60, while in sheet ZK40 containing 1% MM and 1% Th has properties vastly superior to AZ31. The following shows this comparison on the basis of laboratory work.

Extrusions* - T5		1000 psi		
Alloy	%E	TYS	CYS	TS
ZK60	9	45	38	53
QZ66-2MM	6	49	50	58

Sheet* - H26		1000 psi		
Alloy	%E	TYS	CYS	TS
AZ31	8	36	31	43
ZE41-1Th	8	40	40	49

*Fabricated from ingots

Comparative properties of extrusions made from pellets and ingot clearly indicate a very marked superiority of the pellet fabrications. Melt additions, however, have smaller effects in pellet than in ingot fabrications.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

M. E. SORTE
Colonel, USAF
Chief, Materials Laboratory
Directorate of Research

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INTRODUCTION

This is the final report on Part 1 of Contract No. AF(600)19147 sponsored by the Materials Laboratory, Directorate of Research, W.A.D.C. and covers the period July 1, 1953 through December 31, 1954.

This work is a continuation of the development of high strength magnesium alloys, primarily through alloy studies. The emphasis in previous work[1-3] has been primarily in the evaluation of commercial alloys fabricated from pellets, development of extrusion and rolling techniques to obtain optimum properties, and the co-extrusion of pellet mixtures to obtain alloys that cannot be produced by conventional alloying (due to solubility or incompatibility limitations). The present work was directed primarily toward the development of new high strength alloys through selected melt additions to Mg-Zn-Zr base alloys. The Mg-Zn-Zr system was selected as a basis for new alloys because of its excellent combination of properties in extrusions. The new alloys have been studied in pellet and/or ingot fabrications in order to determine the relative merits of each and to carry out the survey in the most complete, yet most efficient, manner.

EXPERIMENTAL RESULTS

A) Effect of 0.5 - 6% Zn on ZK and ZK + 12A33 Pellet Extrusions (Table I, Fig. 1)

1) All the Mg-Zn-Zr base alloys have good extrudability, but co-extrusion with 12% A33 generally results in surface tearing.

2) The strength, ductility, toughness, and corrosion rate of Mg-Zn-Zr pellet extrusions generally increase with increasing Zn content.

3) The unusually high strength (particularly TYS) and low ductility of ZK10 pellet extrusions observed in past work[2] was confirmed and is attributed to the presence of considerable amounts of oxide and second phase (probably Zn-Zr) in the structure. (Fig. 2)

4) The addition of 12% A33 increases the strength, decreases the ductility and toughness, and reduces the sensitivity of the Mg-Zn-Zr pellet extrusions to annealing.

B) Effect of Melt Additions to ZK60 and ZK60 + 5A20 (Tables 2-5)

Extrusion

1) The hot short speed of ZK60 pellet extrusions is decreased drastically by the addition of only 0.2% Ca and slightly by 1% additions of Th, MM, and Ag. This reduction in hot short speed is directly proportional to the content of the additions.

2) The addition of Th offers a small but significant increase in the CYS of ZK60 and a somewhat larger increase in TYS. The optimum Th content appears to be about 0.8%.

3) The addition of Th is more beneficial to the properties of ZK60 than those of ZK10 pellet extrusions.

4) Addition of MM and Ca increases the TYS of ZK60 appreciably but has no effect on CYS. The effect of 1% Ag is negligible.

5) The co-extrusion of 5% A20 with these alloys decreases the sensitivity of the extrusions to annealing but does not significantly improve their properties.

6) Simultaneous additions of 1% Th, 1% Ag, 1% MM, and 0.1% Ca are not significantly beneficial to ZK60 pellet extrusions.

7) MM and Ag interact favorably on the properties, extrudability, and corrosion resistance of ZK60 pellet extrusions, while MM and Ca interact unfavorably on properties.

Rolling

8) The hot rollability of ZK60 pellet extrusions is drastically decreased by the addition of Ca and is relatively unaffected by Th, MM, and Ag; cold rollability is improved somewhat by all four of the additions but particularly Ca and MM.

9) The properties of ZK60 sheet rolled from pellet extrusions are greatly improved by all of the additions, particularly Ca. Illustrative properties are presented below:

Alloy	%E	1000 psi TYS	CYS	TS	NBE
ZK60	8	39	25	47	8
ZK50-.2 Ca	9	40	37	49	14
ZK50-1.3 Th	7	42	35	47	9
ZK30- .7 MM	7	42	35	47	9
ZK50- .9 Ag	7	45	34	51	5

Corrosion

10) The corrosion rate of ZK60 pellet extrusions is increased by Ag and decreased by MM and Ca. The corrosion rate of ZK60-Th has varied considerably, but is apparently equal to or slightly less than that of ZK60.

Metallography

11) The grain size of ZK60 pellet extrusions is not appreciably affected by melt additions of Ag, Ca, MM, or Th (Fig. 3).

C. Effect of Melt Additions on ZH61 Ingot and Pellet Fabrications

Extrusion (Table 6)

1) The hot short speed of ZH61 extrusions is decreased by MM, Ag, Ba, Pd, Sr, and Cu, unaffected by Ca (.05% max.), Cd, Bi, Pb, and Cr, and increased by Li and Hg. The effect of these additions is less in pellet than in ingot extrusions.

2) The addition of 3-6% Ag to ZH61 results in a considerable strength increase, which is greater in ingot than pellet extrusions as illustrated below:

Extrusions (T5)	Ingot %E	Ingot 1000 psi TYS	Ingot CYS	Ingot TS	Pellet %E	Pellet 1000 psi TYS	Pellet CYS	Pellet TS
ZH61	9	45	37	52	8	50	49	55
ZH61-6Ag	7	47	45	55	6	50	53	57

The Ag additions also increase the ageability of ZH61 and decrease the sensitivity of its properties to extrusion conditions.

3) The addition of Pb in pellet and Pb and Cu in ingot ZH61 extrusions gives slight strength increases, while the other additions have negligible effects or are slightly deleterious.

4) The properties of pellet extrusions are vastly superior to those of ingot extrusions as illustrated below with the average properties of the ZH61 base alloys.

Extrusion	%E	1000 psi TYS	1000 psi CYS	1000 psi TS	NBE
Pellet	8	50	48	55	8
Ingot	8	45	38	51	11

Rolling

5) The poor hot rollability of cast ZH61 is significantly improved by MM and Ag, relatively unaffected by Hg, Cr, and Cd, and impaired by the other additions. The cold rollability of ZH61 sheet is also significantly improved by 2% MM.

6) The sheet properties of ZH61 are improved greatly by 2% MM and slightly by Ag and Cu.

Alloy	%E	1000 psi TYS	1000 psi CYS	1000 psi TS
ZH61	7	27	21	38
ZH61-2MM	8	38	35	46

Formability

7) The poor formability of ZH61 is improved considerably by Ag, MM, Li, and Ba and slightly by Sr, Cu, and Bi. These improvements are larger in ingot than in pellet extrusions.

Corrosion

8) The additions to ZH61 are generally either more beneficial or less deleterious in pellet than in ingot extrusions. MM is beneficial, and Ag and Bi are deleterious in both ingot and pellet ZH61 extrusions.

Metallography (Figs. 4-6)

9) The grain size of pellet is considerably smaller than that of ingot of the same composition before and after extrusion.

10) Several additions increase compound rating, but none markedly affect grain size of cast or extruded ZH61.

D) Mg-Ag-Zn-Zr Containing Th and Rare Earths (Table 7)

Extrusion

1) The hot short speed of the Mg-Ag-Zn-Zr alloys is increased by the addition of Th or rare earths.

2) Addition of Th and rare earths has little or no effect on the properties of the base alloys.

3) Increasing Ag from 3 to 6% increases strength, while increasing Zn from 3 to 6% slightly increases strength and significantly decreases the sensitivity of properties to extrusion conditions.

Alloy	Lowest Strength * %E	Lowest Strength * 1000 psi TYS	CYS	TS	Highest Strength* %E	Highest Strength* 1000 psi TYS	CYS	TS
QZ66 - 2 MM	6	45	45	54	5	49	55	58
QZ63 - 2 MM	8	40	34	51	7	45	49	54
ZQ63- 2 MM	9	42	40	52	6	46	47	55

*Obtained on laboratory extrusions - T5 condition

4) The large strength advantage (particularly CYS) of QZ66-2MM, the optimum composition, over ZK60 extruded under comparable conditions is illustrated below:

Extrusion - T5	%E	1000 psi TYS	CYS	TS
ZK60	9	45	38	53
QZ66-2MM	6	49	50	58

Rolling

5) The poor hot rollability of the Mg-Ag-Zn-Zr alloys, though unaffected by 1% MM or less, is impaired by 2% MM. The rollability of extrusions is better than that of cast ingots and is unaffected by MM.

6) The addition of 2% MM is very beneficial to the cold rollability of QZ66 and ZQ63 and slightly beneficial to QZ63.

7) The hot and cold rollability of QZ63 alloys is superior to that of QZ66 and ZQ63 alloys.

Formability

8) All of the alloys except the QZ63 base (9-11t) have relatively good formability (5-7t).

Corrosion

9) The poor corrosion resistance of Mg-Ag-Zn-Zr is not markedly impaired by the addition of Th or rare earths.

Metallography

10) The addition of MM appreciably increases the solidus of the Mg-Ag-Zn-Zr alloys.

11) MM increases the compound rating of the Mg-Ag-Zn-Zr alloys but does not appreciably affect grain size.

E) Mg-MM-Th-Zn-Zr (Table 8)

1) Addition of 1% MM and 1-3% Th to ZK40 and ZK60 extrusions appreciably increases strength but reduces hot short speed to about 5 fpm.

2) Mg-MM-Th-Zn-Zr ingots have a hot rolling range of about 200F and good cold rollability (about 50%).

3) The excellent sheet properties of these alloys are considerably better than those of AZ31. The alloys containing 6% Zn have slightly better properties than those containing 4% Zn.

		1000 psi		
Alloy	%E	TYS	CYS	TS
AZ31	8	36	31	43
ZE41-1Th	8	40	40	49
ZE41-2Th	6	41	39	49
ZE61-2Th	9	41	41	50
ZE61-3Th	8	42	42	50

4) The minimum bend radius of the extrusions is 6-8t.

5) The alloys containing more than 1% Th have poor corrosion resistance, which appears to decrease with increasing Th/Zn ratio.

CONCLUSIONS

1) The best combination of strength, ductility, and toughness of Mg-Zn-Zr + Mg-Al pellet extrusions is obtained with ZK60. Addition of Mg-Al (A20 or A33) decreases the sensitivity of the extrusions to annealing but does not improve the overall properties of the Mg-Zn-Zr base.

2) Mg-Ag-Zn-Zr containing Th or rare earths to improve workability are the highest strength extrusion alloys developed in this work. QZ66-2MM appears to be the optimum composition.

3) Mg-Zn-Zr alloys containing Th and MM have excellent sheet properties. The optimum composition, ZK40-1MM-1Th, is considerably stronger than AZ31.

4) The properties of pellet extrusions are vastly superior to those of ingot extrusions. Melt additions have a greater effect in ingot than in pellet extrusions.

EXPERIMENTAL WORK

A) Alloys

Melts of the desired composition were cast into rolling or extrusion ingots and/or atomized into pellets. The ingots were scalped to remove the cast surface, while the pellets were used as produced. Samples taken from the melt and/or the pellets were chemically analyzed.

B) Extrusion

The ingots and pellets were preheated, loaded into the container, and forward extruded under various conditions for evaluation of the alloys. The hot short speed was determined by gradually increasing speed until hot shorting was noted on the extrusion. Samples were taken from the extrusions for testing.

C) Rolling

Cast and extruded stock was preheated to the rolling temperature and reduced to the desired thickness at a reduction of generally 20-30% per pass. The sheet was reheated to temperature as often as necessary to prevent cold cracking. The sheet was then annealed and warm or cold rolled to the final gauge. Samples for testing were taken from sheet as rolled and annealed at various temperatures.

The hot rolling range of the alloys studied herein was determined by rolling small slabs at temperatures between 400 and 1000F. Sheet free from alligatoring, transverse cracking, and serious edge cracking was considered satisfactory. The cold rollability of the alloys was determined by cold rolling annealed sheet at 1-2% per pass until transverse or serious edge cracking was noted. This total cold reduction was taken as the maximum cold rollability.

D) Temper and Composition Designations

ASTM designations for the chemical composition of the alloys have been used throughout the report. The designation consists of not more than two letters representing the alloying elements present in the greatest amount followed by their respective percentages rounded off to whole numbers. The letters are arranged in order of decreasing percentages or in alphabetical order if of equal percentages. For example:

Composition	ASTM Designation
Mg-6Zn-.6 Zr-6Ag	QZ66
Mg-6Zn-.6 Zr-1Th	ZH61
Mg-4Zn-.6 Zr-1MM	ZE41

Experimental alloys are designated by the base alloy followed by the addition studied, such as

Mg-6Zn-.6 Zr-6Ag+2MM	QZ66-2MM
Mg-6Zn-.6 Zr-1Th+2Cu	ZH61-2Cu

The temper designations used throughout the report and summarized below are essentially the same as those used for Al alloys.

F - As fabricated	T6-Solution heat treated then aged
T4 - Solution heat treated	H26-Hard anneal (sheet)
T5 - Aged	O - Soft anneal (sheet)

E) Testing

Tension and compression tests were made according to ASTM specifications with the exception that tensile test bars were 6 1/2" instead of a minimum of 8" long. The relative toughness (in in. lbs) of the fabrications was determined from static notch-bend tests on a Tinius Olsen Stiffness Testing Machine.

The formability of the alloys was obtained by finding the minimum radius at which a 90° bend could be made without cracking. This value is reported as a ratio of the minimum radius to the thickness of the sample (t).

The relative corrosion resistance of the alloys was determined by alternate immersion of samples in 3% NaCl at 95F for 2 weeks. The corrosion rate is reported in mcd units (milligrams weight loss per square centimeter of surface area per day on test).

DISCUSSION

A) Effect of Zn on ZK and ZK+12A33 Pellet Extrusions

A review of past work[1-3] on the extrusion of Mg-Zn-Zr pellets revealed that properties equivalent to those of ZK60 were obtained at lower zinc contents (i.e. ZK10 and ZK20). This work was undertaken in an attempt to substantiate the limited data obtained in earlier work[2]. Co-extrusion with A33

(Mg-33%Al) pellets was also included in the program to determine the effect of interference hardening (precipitation of Al_3Zr) on the mechanical properties. Six Mg-Zn-Zr alloys (Table 1A) varying in Zn content from 1/2 to 6% were selected for extrusion with and without 12% A33.

All the Mg-Zn-Zr alloys have good extrudability, but co-extrusion with 12% A33 generally results in surface tearing (Table 1B). The mechanical properties plotted against Zn content in Fig. 1 confirm the past data in that ZK10 has unusually high strength. ZK10 has higher TYS and slightly lower CYS than ZK60 in the as-extruded (F) condition. The strength of ZK10 extrusions is only slightly lowered by an anneal which drastically lowers the strength of ZK60. The poorer ductility and toughness of ZK10 in the F and particularly the T4 tempers should be noted. In spite of the high tensile properties and temperature resistance exhibited by ZK10, ZK60 has the best combination of strength, ductility, and toughness as illustrated below:

	F					T4				
		1000 psi					1000 psi			
Alloy	%E	TYS	CYS	TS	NBE	%E	TYS	CYS	TS	NBE
ZK10	5	51	42	54	7	6	49	38	50	8
ZK60	10	45	45	52	10	18	32	32	44	16
ZK10-12A33	2	52	50	53	5	6	52	46	54	8
ZK60-12A33	2	50	52	52	5	6	49	47	55	6

When both alloys are co-extruded with 12% A33, their properties are equivalent. The addition of A33 decreases ductility and toughness and increases strength. Annealing the extrusions gives a better combination of strength and ductility, but these properties are not significantly better than those of ZK60 in the as-extruded condition. Although the addition of 12% A33 appears to be beneficial to the T4 properties of ZK10, it did not improve the overall combination of properties of the other Mg-Zn-Zr alloys.

Metallographic examination of the pellet extrusions revealed that ZK10 contained a considerable amount of oxide and a second-phase tentatively identified as Zn-Zr compounds. These materials are apparently responsible for the unusual properties of ZK10. Zn-Zr compound, present either as large particles or fine precipitate, was found to a varying degree in all of the alloys. The amount of this phase present in the extrusion correlated qualitatively with the properties observed - lower ductility and higher strength, particularly TYS. Photomicrographs of the microstructure of the extrusions are shown in Fig. 2.

In later work new batches of ZK10 and ZK60 pellets were atomized and extruded under comparable conditions. The properties listed below show that ZK60 is superior to ZK10 and that the high strength previously obtained on ZK10 was apparently due to heavily oxidized pellets containing a considerable amount of Zn-Zr compounds.

		1000 psi		
Alloy	%E	TYS	CYS	TS
ZK10	4	41	37	48
ZK60	9	43	43	52

The corrosion rate of the Mg-Zn-Zr alloys listed in Table 1B are erratic due to variation in purity of the pellets. The rates of ZK00, ZK30, and ZK60 appear sufficiently accurate to indicate that corrosion resistance decreases with increasing Zn content.

B) Effect of Melt Additions to Mg-Zn-Zr

1) Initial Survey

Past alloy survey work[4] was thoroughly reviewed in an attempt to select the additions most likely to improve the properties of ZK60. Four elements, Th, MM, Ag, and Ca, were selected. Co-extrusion with A20 was included in the program in hopes of obtaining strength improvements through interference hardening. The concentration of the additions was set at 2% Th, 1%MM, 1%Ag and 0.1% Ca. The analyses of the alloys (Table 2A) show that the zinc content of all the quaternary alloys, particularly ZK60-MM, was low. The alloys were extruded into strip and then rolled to evaluate them in the form of sheet and extrusions.

The addition of 0.2% Ca decreases the hot short limit of ZK60 from 30 to 6 fpm and its hot rolling range from 500 to 50F (Table 2B). The alloys containing Th, Ag, and MM were satisfactorily extruded at 20 fpm and hot rolled over a range of at least 300F. Co-extrusion of these alloys with 5% A20 occasionally resulted in a poorer extruded surface but had no effect on hot rollability or hot short speed. Cold rollability of ZK60 was appreciably improved by all of the melt additions (particularly Ca and MM) and considerably decreased by A20 additions.

The mechanical properties of aged extrusions and cold rolled strip are presented in Table 2C. The properties of ZK60 are improved considerably in sheet and slightly in extrusions by the melt additions. The properties of ZK30-MM given below, though lower than ZK60, are very good in view of its lower Zn content. All of the additions increased the CYS of ZK60 sheet by 10,000 psi with no loss of ductility or toughness.

	Extrusions -F				Rolled Strip - H26				
		1000 psi				1000 psi			
Alloy	%E	TYS	CYS	TS	%E	TYS	CYS	TS	NBE
ZK60	14	43	45	54	8	39	25	47	8
ZK50-.2Ca	11	49	48	56	9	40	37	49	14
ZK50-1.3Th	12	46	48	55	7	42	35	47	9
ZK30-.7MM	8	47	43	55	7	44	35	47	9
ZK50-.9Ag	14	43	47	52	7	45	34	51	5

ZK50-Ca has the best combination of mechanical properties but has poor workability. The Mg-Zn-Zr alloys containing MM, Ag, Th have slightly lower properties than ZK50-Ca but better workability. The addition of A20 is not beneficial to the properties of either sheet or extrusions.

The microstructure of the pellet extrusions is shown in Fig. 3. It may be seen that the melt additions have little, if any, effect on the fine grain size of the ZK60 base. The stringers of large grains present in some of the photomicrographs are apparently due to the recrystallization of some of the pellet particles during extrusion.

The corrosion resistance of the ZK60 base is slightly improved by Ca, MM, and Th and decreased by Ag. Addition of 5% A20 results in significantly higher corrosion rates.

Th and MM appear to be the best overall additions to ZK60. Ca and Ag have desirable effects on mechanical properties, but Ca is deleterious to hot workability, and Ag lowers corrosion resistance. Although Th yields slightly better properties than MM in extrusions, they are equivalent in rolled strip.

2) Effect of Zn and Th on Mg-Th-Zn-Zr

Since Th improved the properties of ZK60 pellet extrusions, a factorial experiment was run to determine the effect of varying the Zn and Th content. A factorial experiment was chosen in preference to a conventional experiment in order to determine the interaction between Zn and Th and to ascertain the significance of the results. Extrusion variables, as well as Zn and Th content, were included in order to evaluate the Mg-Th-Zn-Zr alloys over a wide range of conditions. The Zn content was set at 1.5 and 6%, while Th levels of 0 and 2% were selected. The actual melts, however, varied considerably from the nominal compositions (Table 3A). The Th content was quite low (1.3 - 1.4%) in both Th alloys, and the Zn content of the nominal ZK60-2Th alloy was 4.4%.

The extrudability, average mechanical properties, and corrosion resistance are presented in Table 3B. The addition of Th is deleterious to the extrudability of Mg-Zn-Zr, particularly at low Zn (ZK10). Although ZK10 has a much higher hot short limit than ZK60 (80 compared to 30 fpm), both alloys containing Th have not had comparable extrudability, hot shorting at about 20 fpm. The effects and interaction of Zn and Th on the mechanical properties and corrosion resistance of the Mg-Th-Zn-Zr alloys are given below. The properties of ZK40-Th have been adjusted to compensate for its low Zn content. The probability that an effect is real is included in parentheses. An effect having a probability of about 95% or greater is considered significant.

Factors	%E	TYS	CYS	TS	Corrosion Rate(mcd)
Zn (1.5 → 6%)	+2.2(69)	+1.7(34)	+9.0(100)	+5.0(99)	+2.9(96)
Th (0→1.3%)	+1.5(51)	+4.5(76)	+2.6(94)	+1.4(56)	-1.3(64)
Zn-Th Interaction	-3.8(92)	+0.5(10)	+1.2(60)	+0.2(08)	-1.5(71)

The corrected results indicate that increasing Zn from 1.5 to 6% results in a large and significant increase in CYS, TS, and corrosion rate and a slight rise in ductility and TYS. The addition of Th results in a significant increase in CYS and possible increases in ductility, TYS, TS, and corrosion resistance. The Zn-Th interaction gives the difference in the effect of Th at high (ZK60) and low Zn (ZK10) or the equivalent effect of Zn at high (1.3%) and low (0%) Th. The results show that the effect of Th on TYS and TS is independent of Zn content; however, its other effects are not. The addition of Th increases ductility to a greater extent in ZK10 (+5.3%) than ZK60 (-2.3%), results in a larger gain in CYS in ZK60 (3800 psi) than ZK10 (1400), and decreases corrosion rate more in ZK60 (-2.8 mcd) than ZK10 (+0.2 mcd).

It is interesting to note the very large increase in CYS when the Zn content is increased. This clearly demonstrates the superiority of ZK60 over ZK10. The addition of Th is more beneficial to the properties of ZK60 than ZK10 and offers appreciable gain in mechanical properties and corrosion resistance with a small loss in extrudability.

3) Simultaneous Additions of Th, MM, Ca, and Ag to ZK60

Another factorial experiment[5-6] was run to determine the effects and interaction of Th, MM, Ca, and Ag on ZK60. This work was done to more thoroughly evaluate these additions and to explore the possibility of obtaining an alloy system with better properties than those of the simple quaternaries. The additions to ZK60 were set at the following levels:

Addition	Low Level	High Level
Th	0%	1%
MM	0%	1%
Ca	0%	0.1%
Ag	0%	1%

The Ca content was set at 0.1% since previous work had indicated 0.24% Ca was very deleterious to extrudability. Sixteen alloys (Table 4A), combinations of the above additions, were atomized and extruded into strip for evaluation of extrudability, mechanical properties, and corrosion resistance (Table 4B). The overall effects and the significant interactions presented below show that the additions have little, if any, effect on strength properties. Ductility is significantly decreased by MM and appreciably increased by Ca. These two additions also increase TYS slightly. The hot short limit is lowered appreciably by all the additions, while corrosion rate is increased slightly by Ag and decreased significantly by MM.

Effects of Simultaneous Additions

Factor	%E	TYS (1000 psi)	CYS (1000 psi)	TS (1000 psi)	Hot Short Speed(fpm)	Corrosion Rate(mcd)
Mean	6.8	49.0	47.1	53.3	18.5	2.05
Th(0 → 1)	-0.4(30)	-0.0(02)	-0.7(52)	-0.5(44)	-3.8(85)	-0.1(10)
Ca(0 → 1)	+1.6(83)	+1.2(74)	-0.2(13)	+0.5(44)	-4.2(90)	+0.2(14)
Ag(0 → 1)	-0.5(33)	-0.5(38)	+0.5(39)	-0.2(17)	-2.2(62)	+0.8(59)
MM(0 → 1)	-2.2(94)	+1.4(80)	-0.7(52)	+0.1(06)	-1.5(44)	-1.6(89)
Ca -MM int.	-3.1(99)	-1.7(89)	-1.2(74)	-1.6(93)	+1.8(50)	-0.1(06)
Ag -MM int.	-0.2(13)	+2.3(96)	+2.0(95)	+1.9(97)	+3.2(79)	-0.6(46)

Although none of the alloys were significantly better than the ZK60 base, two important interactions were found. The Ag-MM interaction is favorable to strength, extrudability, and corrosion resistance. This means that Ag or MM has either a more beneficial or less detrimental effect on strength, extrudability, and corrosion resistance if the other is present. This is the only interaction which resulted in a significant improvement in strength. On the other hand, Ca and MM interact unfavorably on mechanical properties. This means that Ca or MM is either less beneficial or more detrimental to mechanical properties if the other is present than if the other is absent.

4) Final Evaluation of Th, MM, Ca, and Ag Additions to ZK60

The negligible effects of Th, MM, Ca, and Ag additions (both single and simultaneous) to ZK60 were surprising since earlier work indicated that an appreciable improvement in properties could be obtained by such additions. In order to finally evaluate the additions selected alloys were extruded under carefully controlled conditions and tested. Several new alloys (Table 5A) were atomized and included in this work to determine the effect of Th content and to check the properties of the ZK60 base.

The properties of the alloys, listed in Table 5C, show that Th offers a marginal improvement in the strength of ZK60 extrusions. The optimum benefit is derived at about 0.8% Th. Larger additions decrease strength and extrudability. It is interesting to note that the benefit of 0.8% Th to the CYS of ZK60 varies from -1,000 to +4,000 psi and averages 2,000 psi. This marginal benefit of Th to ZK60 explains the variation observed in previous work. A relatively small variation in extrusion conditions or alloy composition would be sufficient to overshadow the small beneficial effect of the Th. Single additions of 1% MM, 1% Ag, and 0.1% Ca are not beneficial to ZK60.

All of the additions - Th, Ca, and MM - decrease the hot short speed of ZK60 (Table 5B). The addition of Th causes a reduction in extrudability directly proportional to its concentration in ZK60 - about 5 fpm for each per cent.

The formability of the base is improved by single additions of 1.2% or more Th, 1% MM, 1% Ag, and 0.1% Ca. Ca gives the greatest improvement in formability but is the most deletrious to extrudability. The variation found in the corrosion rate is probably due to quality and not necessarily the additions. It appears likely, however, that Ag increases the corrosion rate of ZK60.

C) Effect of Melt Additions to ZH61 Ingot and Pellet Fabrications

1) Introduction

Melt additions of several elements - Ca, MM, Ag, Ba, Cd, Pd, Li, Sr, Cu, Bi, Pb, Cr, and Hg - were made to ZH61 in an attempt to improve the properties of the wrought alloy. ZH61 was selected as the base alloy instead of ZK60 because of its slightly higher strength and better rolling characteristics. The additions were studied in both ingot and pellet fabrications to compare their effects.

The desired elements were added to melts of ZH61, ingots for rolling and extrusion were cast, and the remainder of the metal was atomized. Samples for chemical analyses (Table 6A) were taken from the pellets and several of the ingots. In general good agreement in composition was obtained.

The soluble Zr content of the ZH61 was considerably lowered by 1% Li, and 1% Ba, while the addition of Li also lowered the Th content. Ingots and pellets were extruded under equivalent conditions and evaluated for mechanical properties, extrudability, formability, and corrosion resistance. The alloys in ingot form were rolled to sheet for evaluation of hot and cold rollability and mechanical properties.

2) Extrusion

The hot short speed of ZH61 ingot extrusions (Table 6B) is decreased by the addition of MM, Ag, Ba, Pd, Sr, and Cu and increased by the addition of Li and Hg. The elements generally have smaller effects on the hot short speed of ZH61 pellet than on ingot extrusions.

Properties of aged extrusions (Table 6C) indicate that Ag is, by far, the most beneficial addition to ZH61. Although Ag increases the tensile properties only slightly, it raises the CYS considerably. The increase in CYS varies almost lineraly with increasing Ag content up to 6% Ag. Toughness of ZH61 is unaffected by 3% Ag but is seriously decreased by 6% Ag. It is interesting to note that the benefit of Ag is about twice as great in ingot than in pellet extrusions as illustrated below.

	Ingot				Pellet			
		1000 psi				1000 psi		
Extrusions (T5)	%E	TYS	CYS	TS	%E	TYS	CYS	TS
ZH61	9	45	37	52	8	50	49	55
ZH61-6Ag	7	47	45	55	6	50	53	57

The other additions have small, if any, effect on the properties of ZH61. Cu and Pb in ingot and Pb in pellet extrusions appear to offer slight strength increases. Li, Sr, and Bi in ingot and MM, Ba, Sr, Cu, and Bi in pellet extrusions are slightly deletrious. Additional work would be required to determine whether these slight changes in properties are significant. Toughness is reduced by MM, Ag, Ba, Sr, Cu, and Bi and increased by Li. Comparison of the properties of ingot and pellet extrusions shows that the latter have higher strengths, particularly CYS, and lower toughness.

The comparative properties of all the pellet and ingot extrusions are given below:

Extrusion	%E	1000 psi TYS	1000 psi CYS	1000 psi TS	NBE
Pellet	8	50	48	55	8
Ingot	8	45	38	51	11

This advantage in strength of pellet over ingot extrusions is somewhat greater at low extrusion reductions and smaller at high reductions. It may also be noted that the melt additions are less beneficial to pellet than to ingot extrusions. The addition of 6% Ag, for example, increases the CYS of ZH61 8,000 psi in ingot extrusions and only 4,000 psi in pellet extrusions. Several other additions which are slightly beneficial in ingot extrusions have negligible effects in pellet extrusions.

Because of the more beneficial effect of the additions in ingot than in pellet extrusions, future alloy survey work will be done with ingots, and the promising alloys will be checked in pellet fabrications.

3) Rolling

The hot rollability of ZH61 ingots (Table 6B) is generally poor. Although the ZH61 base can be hot rolled over a reasonably wide range (200F), it experiences surface checking. The poor surface of ZH61 sheet is improved by two elements - 2-4% MM and 3-6% Ag. Both additions narrow the rolling range of ZH61 but eliminate surface checking. Hg, Cr, and Cd have no effect, while Pd, Pb, and Cu narrow the rolling range of ZH61 with no surface improvement. ZH61 containing Ca, Ba, Li, Sr, and Bi could not be successfully hot rolled at any temperature within the range investigated (600-900F). The cold rollability of ZH61 is improved considerably by 2% MM, unaffected by Cd, Pd, Cu, Pb, Cr, and Hg, and decreased by Ag and 4% MM.

The mechanical properties of sheet given in Table 6D reveal that the addition of 2% MM is very beneficial to ZH61.

Alloy	%E	1000 psi TYS	CYS	TS
ZH61	7	27	21	38
ZH61-2MM	8	38	35	46

The above data illustrate the large strength increases that are obtained with no loss of ductility. The addition of Ag and Cu results in smaller strength increases, while Cd, Pd, and Cr have no effect.

4) Formability

The minimum bend radii of the ingot and pellet extrusions are listed in Table 6B. Since formability varies somewhat with extrusion conditions, a range is given. The poor formability of ZH61 ingot extrusions is improved considerably by Ag, MM, Li, and Ba and slightly by Sr, Cu, and Bi. Cd, Pd, Pb, Cr, and Hg have little or no effect. The additions are less beneficial in pellet extrusions; Ag, Li, and possibly Cu and Bi are beneficial, while MM appears deletrious to formability.

5) Corrosion

The corrosion rates of the extrusions,given in Table 6E, indicate that in general pellet extrusions are equal to or better than ingot extrusions. The only notable exceptions are ZH61-6Ag and ZH61 (high reduction only). On the other hand, many of the additions which are deletrious in ingot extrusions have no effect or are even slightly beneficial in pellet extrusions. This is best illustrated by ZH61-2Pb, which has a corrosion rate of 0.5 - 1.2 mcd in pellet extrusions and 100-200 mcd in ingot extrusions. MM is the most beneficial addition to ZH61,while Ba, Li, and Pb are possible additions for improved corrosion resistance of pellet extrusions. Ag and Bi are detrimental to both ZH61 ingot and pellet extrusions, while Cu, Pb and Pd may increase the corrosion rate of the former.

6) Metallography

The microstructures of the cast ingot and selected pellet alloys are shown in Figs. 4 and 5. The fine grained ZH61 ingot (.002"), is decreased slightly by Ca (.001") and possibly Cr (.0015") and increased by Cd (.003"), 2% MM (.004"), and Bi (.005"). The other additions have little or no effect on grain size. Additional second phase material is present in ZH61 containing MM, Ag, Pd, Sr, Cu, and Pb. Considerable porosity is present in the ZH61-Bi alloy. Solution heat treatment has a negligible effect on grain size and results in an appreciable reduction in second phase constituent only in ZH61-Ag. The grain size of the pellets (Fig. 5) is about 0.0002" or one tenth of that of ingot. It is also interesting to note the greater amount of second phase in pellets than in ingots. These characteristics of pellets are apparently due to their fast cooling rate.

The photomicrographs in Fig. 6 show that extrusions made from pellets have a finer grain size than those fabricated from ingots. This is particularly true at low extrusion reductions, which are not sufficient to completely refine the grain size of the cast ingot but are adequate to produce a fine grained pellet extrusion. The grain size of the ZH61 ingot extruded at high reductions is quite small (.0001"), but that of the pellet extrusion is even smaller--.00005" - .0001" at low reductions and $<$.00005" at the high reductions. The finer grain size of the pellet extrusions is responsible for their higher strength (particularly CYS).

The ZH61-2MM and ZH61-6Ag extrusions are included in Fig. 6 to illustrate the size and distribution of a second phase. It is readily apparent that the second phase is much finer and more evenly distributed in pellet than in ingot extrusions. This is another result of the finer structure in pellets than in ingots. The finer size and better distribution of second phase material in pellet extrusions may be the major factor in the better corrosion resistance of alloys extruded from pellets than from ingots.

D) <u>Mg-Ag-Zn-Zr Alloys Containing Th and Rare Earths</u>

1) <u>Introduction</u>

The favorable interactions of MM and Ag in ZK60 and the excellent mechanical properties of ZH61 + 3-6 Ag led to a further study of these alloys. The additions of Th, MM, and Di*were made to one or more of the following base alloys-QZ66(6 Ag - 6Zn - .7 Zr), QZ63 (6 Ag - 3 Zn - .7 Zr), and ZQ63 (3 Ag - 6 Zn - .7 Zr). The analyses of the alloys

*didymium

studied are given in Table 7A. These alloys were cast into ingots for extrusion and rolling. The extrusion program was completed, but time did not permit the rolling of all of the alloys and the determination of the properties of the most promising alloys in pellet extrusions.

2) <u>Extrusion</u>

The addition of rare earths or Th is beneficial to the extrudability of Mg-Ag-Zn-Zr alloys containing 6% Zn (Table 7B). The hot short speed of QZ66 and ZQ63 is increased from 6 to 12 and 20 fpm respectively. Although MM has little or no effect on the extrudability of QZ63, Th is beneficial, increasing the hot short speed from 12 to 20 fpm.

The alloys were evaluated under a variety of extrusion conditions to select the one with the best combination of properties. The lowest and highest strength properties obtained for representative alloys are given in Table 7C. It is interesting to note that MM, Di, and Th have little, if any, effect on the mechanical properties of the base alloys. The Zn and Ag contents, however, have very pronounced effects. Increasing the Ag content from 3 to 6% results in a significant increase in strength as illustrated by QZ66 and ZQ63. Increasing the Zn content from 3 to 6% greatly improves the range of mechanical properties obtained in the extrusions.

	Lowest Strength*				Highest Strength*			
		1000 psi				1000 psi		
Alloy	%E	TYS	CYS	TS	%E	TYS	CYS	TS
QZ66-2MM	6	45	45	54	5	49	55	58
QZ63-2MM	8	40	34	51	7	45	49	54
ZQ63-2MM	9	42	40	52	6	46	47	55

*Obtained in laboratory extrusions-T5

The QZ66 alloys are only slightly better than the QZ63 alloys at the higher strength level but are vastly superior at the lower strength level. Optimum properties are obtained in the T5 temper although QZ66 containing rare earths or Th also has good properties in the T6 temper. The large strength advantage (particularly CYS) of QZ66-2MM, the optimum composition, over ZK60 extruded under comparable conditions is illustrated below:

Extrusions - T5	%E	TYS	CYS	TS
		1000 psi		
ZK60	9	45	38	53
QZ66-2MM	6	49	50	58

3) Rolling

Additions of MM decrease the hot rolling range of cast Mg-Ag-Zn-Zr alloys (Table 7B). Up to 1% MM has little effect, but 2% MM is sufficient to reduce the rolling range 50F or more. The ZQ63 alloys could not be satisfactorily hot rolled from the cast ingot, while QZ66 and QZ63 had narrow rolling ranges (50 and 100F, respectively). The hot rollability of extrusions is better than that of cast ingots. All of the Mg-Ag-Zn-Zr extrusions are rollable, their range varying from 50F in QZ63 - .2MM to 150F in the QZ63 base alloys. Addition of up to 2% MM has no appreciable effect in QZ66 and QZ63 and is slightly beneficial in ZQ63.

The addition of MM is beneficial to the cold rollability of Mg-Ag-Zn-Zr sheet produced from extrusions, particularly those containing 6% Zn. Up to 1% MM has only a slight effect on the cold rollability of QZ66 and ZQ63, but the addition of 2% MM results in a large improvement. In spite of the large increase in the cold rollability of the Mg-Ag-6Zn-Zr alloys by the addition of 2% MM, the QZ63 base alloys are still better as illustrated below:

Base Alloy	0.2% MM	1% MM	2% MM
QZ66	22	24	35
QZ63	37	40	45
ZQ63	22	29	37

4) Formability

Cold formability, like mechanical properties, varies with extrusion conditions. The minimum bend radii of these alloys generally vary from about 5t at the lower strength level to about 7t at the higher strength level (Table 7D).

All the alloys except the QZ63 base have a very narrow transition range from poor to good formability. In a given condition they may fracture completely at 4t but bend satisfactorily at 5t. The QZ63 base, however, has a wide transition range (about 5-10t) in which slight but definite surface cracking is found. The addition of MM and Th eliminates the surface checking and reduces the minimum bend radius of QZ63 to values comparable to the other alloys. In QZ66 and ZQ63 alloys Th and rare earths have little, if any, effect.

5) Corrosion

These alloys have comparatively poor corrosion resistance (3-4 mcd). Additions of MM appear to be deletrious in small amounts (0.2%) but have little or no effect in larger concentrations (Table 7D). QZ66 and ZQ63 containing 2% MM and QZ63-1MM, for example, have corrosion resistance equivalent to the base alloys. Th and Di, although studied to a lesser extent, appear to have similar effects. It is interesting to note that ageing the extrusions generally lowers the corrosion rate.

6) Metallography

The cast microstructure of the alloys illustrated in Fig. 7 shows that the addition of MM increases the compound rating of the alloy in proportion to its concentration. Increasing the Ag or Zn content from 3 to 6% also increases the amount of compound present, particularly in the as-cast condition. The grain size of the alloys is quite small (about 0.001") and varies little, if at all, with varying alloy content and solution heat treatment. Solution heat treatment results in considerable solution in the alloys containing low MM (0.2%). The QZ63 base, for example, is almost completely homogenized. At higher MM contents the compound rating is only slightly decreased by solution heat treatment. This apparently indicates the Ag and Zn compounds are readily dissolved, while those of MM are not. The solution heat treatment almost completely eliminates the pronounced alloy gradients which exist in the as-cast condition.

The effect of MM on the solidus of cast ingots and extrusions, determined at intervals of 25F, is illustrated below:

Base Alloy	Cast Ingots 0.2MM	1MM	2MM	Extrusions 0.2MM	1MM	2MM
QZ66	800	825	900*	875	875	900
QZ63	825	925	950	900	950	950
ZQ63	750	800	900	875	925	925

*Very slight melting at 850F

This increase in solidus is apparently responsible for the higher hot short speeds of the extrusions containing MM.

E) Mg-MM-Th-Zn-Zr

The beneficial effect of MM on the rollability and properties of ZH61 sheet produced from cast slabs led to a study of this alloy system. Mg-MM-Th-Zn-Zr ingots containing 4-6% Zn, 1%MM and 1-3% Th were evaluated as extrusion and sheet alloys. Their chemical analyses are given in Table 8A.

All of the alloys have low hot short speeds (Table 8B) and should be extruded at 5 feet per minute or less. The mechanical properties of the extrusions (Table 8C) are good. The results in Table 9A show that the alloys have appreciable higher strength (particularly TYS) than ZK60. Since these alloys have poor ageability, their property advantages over ZK60 are somewhat greater in the as-extruded (F) condition.

The alloys may be satisfactorily hot rolled over a range of about 200F. Solution heat treatment improves the rollability of the alloys with a high Th/Zn ratio. Cold rollability is excellent (50%) and varies only slightly among the alloys studied.

The properties of sheet given in Table 8C are illustrative of the excellent combination of strength and ductility that can be produced in these alloys. All of the alloys have considerable higher strength, particularly CYS, than AZ31 rolled under similar conditions.

Alloy	%E	1000 psi TYS	CYS	TS
AZ31	8	36	31	43
ZE41-1Th	8	40	40	49
ZE41-2Th	6	41	39	49
ZE61-2Th	9	41	41	50
ZE61-3Th	8	42	42	50

The only major difference in the properties of the Mg-MM-Th-Zn-Zr alloys is the lower ductility of the ZE41-2Th alloy. The alloys containing 6% Zn appear to have slightly higher strength.

The minimum bend radius (Table 8D) of the extrusions varies from 6 to 8t. ZE61-3Th appears to have the best formability.

The corrosion resistance of ZE41-1Th is good, but that of the other alloys is poor. The corrosion rates of the alloys increase with increasing Th content and Th/Zn ratio.

ZE41-1Th appears to be the optimum composition of these alloys because of its good corrosion resistance and equivalent workability and mechanical properties.

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TABLE I

MG-ZN-ZR + 0,12 A33

A) ANALYSES

Alloy No.	Nominal Composition	% Zn	Soluble %Zr	Insoluble %Zr	% Al
71422	ZK00	0.53	0.59	0.04	—
71424	ZK10	1.23	0.61	0.03	—
71426	ZK20	2.2	0.59	0.04	—
71428	ZK30	3.21	0.58	0.02	—
71430	ZK40	4.1	0.62	0.04	—
71432	ZK60	5.5	0.59	0.04	—
66504	A33	—	—	—	32.9

- Mixed Pellets -

71423	ZK00 (71422) + 12% A33(66504)
71425	ZK10 (71424) + " " "
71427	ZK20 (71426) + " " "
71429	ZK30 (71428) + " " "
71431	ZK40 (71430) + " " "
71433	ZK60 (71432) + " " "

B) EXTRUDABILITY* AND CORROSION RATE

Alloy No.	Composition	Extrusion Surface	Corrosion Rate
71422	ZK00	Good	0.20 mcd
71423	ZK00+12A33	Light tearing	----
71424	ZK10	Good	3.41
71425	ZK10+12A33	Occasional tearing	----
71426	ZK20	Good	1.29
71427	ZK20+12A33	Good	----
71428	ZK30	Good	0.49
71429	ZK30+12A33	Good	----
71430	ZK40	Good	23.5
71431	ZK40+12A33	Light tearing	----
71432	ZK60	Good	0.85/2.0
71433	ZK60+12A33	Deep tearing	----

*See Fig. 1 for mechanical properties

TABLE II

ZK60 AND ZK60 + 5A20 PLUS MELT ADDITIONS

A) ANALYSES

Alloy No.	Nominal Composition	% Zn	Soluble %Zr	Insoluble %Zr	% Other
70615	ZK60	5.50	0.59	0.04	---
70960	ZK60-.1 Ca	4.79	0.61	0.06	0.24 Ca
70961	ZK60-.5MM	2.82	0.60	0.06	0.69 MM
70962	ZK60- 2Th	4.74	0.66	0.08	1.28 Th
70963	ZK60- 1Ag	4.64	0.68	0.06	0.94 Ag
66506	A20	--	--	--	19.7 Al

- Mixed Pellets -

71178	ZK60	(70615) + 5% A20 (66506)
71179	ZK60-.1 Ca	(70960) + " " "
71180	ZK60-.5 MM	(70961) + " " "
71181	ZK60- 2 Th	(70962) + " " "
71182	ZK60- 1 Ag	(70963) + " " "

B) WORKABILITY AND CORROSION RESISTANCE

Alloy No.	Composition	Hot Short Limit (fpm)	Hot Rolling Range (F)	Max. Cold Rollability (%)	Corrosion Rate (mcd)
70615	ZK60	30	500	30	0.93
71178	ZK60+5A20	>20	500	22	3.02
70960	ZK50-.2 Ca	6	50	41	0.62
71179	ZK50-.2Ca+5A20	6	50	33	1.55
70961	ZK30-.7MM	>20	300	37	0.72
71180	ZK30-.7MM+5A20	>20	500	37	1.32
70962	ZK50-1.3Th	>20	500	32	0.88
71181	ZK50-1.3Th+5A20	>20	550	28	1.46
70963	ZK50-.9 Ag	>20	550	33	2.05
71182	ZK50-.9Ag+5A20	>20	500	20	3.96

TABLE II (contd)

ZK60 AND ZK60 + 5A20 PLUS MELT ADDITIONS

C) MECHANICAL PROPERTIES

Alloy No.	Composition	Extrusions - F %E	Extrusions - F 1000 psi TYS	Extrusions - F 1000 psi CYS	Extrusions - F 1000 psi TS	Rolled Strip - H26 %E	Rolled Strip - H26 1000 psi TYS	Rolled Strip - H26 1000 psi CYS	Rolled Strip - H26 1000 psi TS	Rolled Strip - H26 NBE
70615	ZK60	14	43	45	54	8	39	25	47	8
71178	ZK60+5A20	12	44	44	52	--	--	--	--	
70960	ZK50-.2Ca	11	49	48	56	9	40	37	49	14
71179	ZK50-.2Ca+5A20	9	48	45	54	7	42	38	52	8
70961	ZK30-.7MM	8	47	43	55	7	44	35	47	9
71180	ZK30-.7MM+5A20	5	48	43	54	--	--	--	--	
70962	ZK50-1.3Th	12	46	48	55	7	42	35	47	9
71181	ZK50-1.3Th+5A20	11	46	49	55	--	--	--	--	
70963	ZK50-.9Ag	14	43	47	52	7	45	34	51	5
71182	ZK50-.9Ag+5A20	11	43	47	52	--	--	--	--	

TABLE III

MG-TH-ZN-ZR

A) ANALYSES

Alloy No.	Nominal Composition	% Zn	Soluble %Zr	Insoluble %Zr	% Th
72435	ZK10	1.50	0.64	0.06	--
72437	ZK10-2Th	1.30	0.62	0.05	1.27
72436	ZK60	5.90	0.67	0.01	--
72438	ZK60-2Th	4.40	0.70	0.09	1.40

B) PROPERTIES OF PELLET EXTRUSIONS

Alloy No	Composition	Hot Short Speed (fpm)	%E	1000 psi TYS	1000 psi CYS	1000 psi TS	Corrosion Rate (mcd)
72435	ZK10	80	7.5	39.1	32.0	45.9	0.68
72437	ZK10-1.3Th	18	12.8	43.1	33.4	47.1	0.90
72436	ZK60	30	13.5	40.2	39.8	50.8	5.11
72438	ZK40-1.4Th	20	10.8	44.9	42.1	51.4	1.70

TABLE IV

ZK60-AG-CA-MM-TH

A) ANALYSES

Alloy No.	% Zn	Soluble %Zr	Insoluble %Zr	% Th	% Ca	% MM	% Ag
72436	5.90	0.67	0.01	--	--	--	--
72576	5.79	0.70	0.02	0.77	--	--	--
72577	5.91	0.69	0.13	--	0.13	--	--
72578	5.44	0.64	0.05	--	--	--	0.94
72579	6.09	0.71	0.04	--	--	1.09	--
72580	5.88	0.80	0.08	0.90	0.12	--	--
72581	6.05	0.44	0.11	1.47	--	--	0.83
72582	6.01	0.86	0.16	0.46	--	0.99	--
72583	6.16	0.73	0.09	--	0.15	--	0.96
72584	5.98	0.58	0.01	--	0.11	1.04	--
72585	5.80	0.57	0.10	--	--	0.22	0.96
72586	6.17	0.57	0.11	0.45	0.10	--	1.10
72587	6.02	0.52	0.01	0.27	0.11	0.96	---
72588	6.02	0.75	0.09	0.86	--	0.92	1.01
72589	5.92	0.62	0.11	--	0.11	1.06	1.06
72590	5.94	0.72	0.07	0.52	0.14	1.00	1.04

B) PROPERTIES OF PELLET EXTRUSIONS

Alloy No.	Addition To ZK60	Hot Short Speed (fpm)	%E	1000 psi TYS	1000 psi CYS	1000 psi TS	Corrosion Rate (mcd)
72436	--	30	7	50	50	56	3.4
72576	Th	20	7	51	49	56	1.6
72577	Ca	20	8	54	51	57	1.3
72578	Ag	22	2	47	48	53	1.7
72579	MM	17	5	53	49	56	1.1
72580	Th-Ca	17	4	53	51	55	2.2
72581	Th-Ag	17	2	47	48	54	4.2
72582	Th-MM	18	7	50	46	53	1.2
72583	Ca-Ag	15	12	50	51	56	4.9
72584	Ca-MM	18	6	50	46	52	1.2
72585	Ag-MM	25	5	52	51	56	1.4
72586	Th-Ca-Ag	13	11	49	49	54	3.5
72587	Th-Ca-MM	15	2	51	47	53	1.0
72588	Th-Ag-MM	16	4	53	50	55	1.1
72589	Ca-Ag-MM	16	3	53	51	56	1.8
72590	Th-Ca-Ag-MM	17	4	52	50	54	1.1

TABLE V

ZK60 + Th, Ca, and MM

A) ANALYSES OF NEW PELLET ALLOYS

Alloy No.	Nominal Composition	% Th	% Zn	Soluble %Zr	Insoluble %Zr
73844	ZK60	--	5.56	0.66	0.02
73442	ZK60-.5Th	0.82	5.78	0.77	0.14
74106	ZK60-2Th	2.04	5.50	0.56	0.02
73443	ZK60-3Th	3.33	5.91	0.84	0.07

B) WORKABILITY, FORMABILITY, AND CORROSION RESISTANCE

Alloy No.	Composition	Hot Short Limit(fpm)	Min.Bend Radius(t)	Corrosion Rate(mcd)
72436	ZK60	30	11-13	6.3
73844	ZK60	30	11-12	1.07
73442	ZK60-0.8Th	25	12-14	30.0
72576	ZK60-0.8Th	25	10-11	2.59
73586	ZK60-1.2Th	23	9-10	4.58
74106	ZK60-2.0Th	20	----	----
73443	ZK60-3.3Th	13	8-11	4.92
72579	ZK60-1.1MM	25	8-10	1.05
72577	ZK60-0.1Ca	20	6-8	1.13
72578	ZK60- .9Ag	25	9-11	1.7

C) MECHANICAL PROPERTIES (AGED)

		High Strength	1000 psi			Intermediate Strength	1000 psi		
Alloy No.	Composition	%E	TYS	CYS	TS	%E	TYS	CYS	TS
72436	ZK60	11	50	51	56	11	47	46	54
73844	ZK60	7	51	50	56	11	45	44	53
73442	ZK60-0.8Th	8	54	54	58	8	47	48	53
72576	ZK60-0.8Th	11	52	52	58	12	46	45	52
73586	ZK60-1.2Th	8	52	52	57	6	48	44	52
74106	ZK60-2.0Th	12	52	50	55	12	48	46	52
73443	ZK60-3.3Th	4	56	50	56	2	48	44	48
72579	ZK60-1.1MM	5	53	49	56	9	44	44	50
72577	ZK60-0.1Ca	13	51	49	56	16	42	41	51
72578	ZK60-.9Ag	2	47	48	53	--	--	--	--

TABLE VI

ZH61 + Additions

A) ANALYSES

Alloy No.	Nominal Composition	% Th	% Zn	Soluble % Zr	Insoluble % Zr	% Other
73586-P	ZH61	1.23	5.89	0.79	0.10	---
73444-P	ZH61-.05Ca	1.27	5.81	0.81	0.07	0.04 Ca
73445-P	" - 2MM	1.26	5.76	0.70	0.06	2.00 MM
73446-P	" - 4MM	1.15	5.63	0.60	0.06	3.69 MM
73447-P	" - 3Ag	1.17	5.61	0.74	0.06	2.76 Ag
73448-P	" - 6Ag	1.17	5.34	0.68	0.05	5.36 Ag
73449-P	" - 1Ba	1.16	5.84	0.56	0.13	0.90 Ba
73450-P	" - 2Cd	1.21	5.86	0.81	0.08	1.86 Cd
73450-I	" - 2Cd	1.28	5.82	0.80	0.11	2.43 Cd
73451-P	" -.2Pd	1.27	5.70	0.73	0.09	0.23 Pd
73452-P	" - 1Li	0.99	5.69	0.50	0.30	1.08 Li
73453-P	" -.5Sr	1.19	5.94	0.69	0.10	0.44 Sr
73453-I	" -.5Sr	1.17	5.83	0.73	0.11	0.52 Sr
73454-P	" - 2Cu	1.16	5.81	0.81	0.08	1.99 Cu
73454-I	" - 2Cu	1.20	5.81	0.80	0.15	1.96 Cu
73455-P	" - 2Bi	1.08	5.87	0.65	0.02	1.65 Bi
73456-P	" - 2Pb	1.16	6.01	0.75	0.05	1.65 Pb
73457-P	" - 1Cr	1.06	6.06	0.97	0.14	0.0003 Cr
73458-P	" - 2Hg	1.23	5.90	0.90	0.08	1.34 Hg
73458-I	" - 2Hg	1.17	5.69	0.87	0.14	1.26 Hg

B) WORKABILITY AND FORMABILITY

Alloy No.	Composition	Hot Short Speed Pellet	Hot Short Speed Ingot	Hot Rolling* Range (F)	Max. Cold Roll-ability*	Min. Bend Radius*** Pellet	Min. Bend Radius*** Ingot
73586	ZH61	25 fpm	25 fpm	200**	31%	9-10	9-13
73444	ZH61-.05Ca	25	25	nil	--	9-12	8-11
72580	" 0.1 Ca	25	--	---	--	9	----
72582	" - 1MM	20	--	---	--	9-11	----
73445	" - 2MM	15	10	100	47	11-13	6-8
73446	" - 4MM	15	15	50	20	14	7-8
73447	" - 3Ag	25	20	100	23	6-7	5-7
73448	" - 6Ag	20	15	50	21	6-8	4-6
73449	" - 1Ba	18	10	nil	--	8-10	6-8
73450	" - 2Cd	25	25	250**	29	8-10	9-13
73451	" - .2Pd	23	15	100**	27	9	6-13
73452	" - 1Li	25	30	nil	--	7-8	5-7
73453	" - .5Sr	20	10	nil	--	8-10	8-9
73454	" - 2Cu	18	10	50**	34	7-9	5-10
73455	" - 2Bi	25	25	nil	--	8-9	6-10
73456	" - 2Pb	23	23	50**	29	8-10	6-13
73457	" - .5Cr	25	25	200**	32	9-10	11-14
73458	" - 2Hg	25	40	200**	32	8-10	11-14

*Hot rolled from ingots
**Surface checking
***Extruded strip (F)

TABLE VI (Contd)

ZH61 + Additions

C) MECHANICAL PROPERTIES OF EXTRUSIONS - T5

Alloy No.	Nominal Composition	Ingot %E	Ingot TYS (1000 psi)	Ingot CYS (1000 psi)	Ingot TS (1000 psi)	Ingot NBE	Pellet %E	Pellet TYS (1000 psi)	Pellet CYS (1000 psi)	Pellet TS (1000 psi)	Pellet NBE
73586	ZH61	9	45	37	52	13	8	50	49	55	9
73444	ZH61-.05Ca	11	44	37	51	13	10	52	48	56	9
72580	ZH61-.1 Ca						6	51	49	55	10
72582	ZH61- 1 MM						8	51	47	54	8
73445	ZH61- 2 MM	6	46	36	49	6	4	54	46	56	5
73446	ZH61- 4 MM	6	44	38	47	4	1	56	48	56	4
72581	ZH61- 1 Ag						5	46	47	52	12
73447	ZH61- 3 Ag	9	47	42	55	12	5	50	51	55	9
73448	ZH61- 6 Ag	7	47	45	55	6	6	50	53	57	6
73449	ZH61- 1 Ba	9	44	38	50	6	5	50	47	54	5
73450	ZH61- 2 Cd	9	46	36	53	14	12	51	49	55	10
73451	ZH61-.2 Pd	9	44	36	51	13	9	48	49	55	9
73452	ZH61- 1 Li	9	41	34	49	17	10	46	48	53	10
73453	ZH61-.5 Sr	8	43	35	50	9	9	51	47	55	6
73454	ZH61- 2 Cu	6	47	39	52	9	8	51	47	55	8
73455	ZH61- 2 Bi	6	42	35	50	12	6	46	46	52	7
73456	ZH61- 2 Pb	9	46	39	53	13	8	51	50	56	9
73457	ZH61-.5 Cr	9	45	38	53	13	8	50	49	55	9
73458	ZH61- 1 Hg	9	45	38	53	13	11	51	49	56	9
	Average	8.2	44.8	37.7	51.4	10.8	7.5	50.4	48.5	55.1	7.8

D) MECHANICAL PROPERTIES OF SHEET* - H26

Alloy No.	Nominal Composition	%E	TYS	CYS	TS
73586	ZH61	7	27	21	38
73586	ZH61	4	35	25	47
73445	ZH61-2MM	8	38	35	46
73446	" -4MM	3	30	24	36
73447	" -3Ag	6	38	25	45
73448	" -6Ag	7	37	29	48
73448	" -6Ag	4	38	35	50
73450	" -2Cd	9	33	20	44
73451	"-.2Pd	8	33	20	44
73454	" -2Cu	9	34	28	46
73457	"-.5Cr	11	28	21	41

*Rolled from ingots

TABLE VI (Contd)
ZH61 + Additions

E) CORROSION RATE(mcd) OF EXTRUSIONS (F)

Alloy No.	Composition	High Reduction Ingot	High Reduction Pellet	Low Reduction Ingot	Low Reduction Pellet
73586	ZH61	1.79	4.58	1.83	1.44
73444	ZH61-.05Ca	1.47	1.43	1.90	0.76
72580	" -0.1Ca	--	2.23	---	1.11
72582	" - 1MM	--	1.45	---	0.82
73445	" - 2MM	0.86	0.91	0.98	0.64
73446	" - 4MM	1.10	1.26	1.38	0.87
72581	" - 1Ag	----	4.57	---	5.60
73447	" - 3Ag	2.74	6.07	2.28	2.71
73448	" - 6Ag	3.77	5.52	2.98	3.25
73449	" - 1Ba	1.48	1.19	2.32	0.70
73450	" - 2Cd	2.91	1.56	1.36	1.24
73451	" -0.2Pd	18.07	2.23	3.20	1.50
73452	" - 1Li	1.23	1.11	1.43	0.74
73453	" -0.5Sr	1.55	1.51	1.70	0.65
73454	" - 2Cu	2.48	1.77	6.09	1.80
73455	" - 2Bi	23	7.72	19.1	6.58
73456	" - 2Pb	>100	1.24	81.	0.49
73457	" -0.5Cr	1.14	1.29	1.45	0.92
73458	" - 1Hg	1.78	1.36	2.25	0.95

TABLE VII

Mg-Ag-Zn-Zr + Th and Rare Earths

A) ANALYSES

Alloy No.	Nominal Composition	% Ag	% Zn	Soluble %Zr	Insoluble %Zr	% Other
75231	QZ66	5.85	5.84	0.58	0.16	--
74206	QZ66-.2MM	6.01	5.43	0.69	0.08	0.20 MM
74207	QZ66- 1MM	5.88	4.47	0.67	0.05	1.06 MM
74208	QZ66- 2MM	5.90	4.49	0.66	0.10	2.04 MM
75232	QZ66- 2MM	5.91	5.97	0.75	0.13	1.91 MM
75235	QZ66- 2Di	5.85	5.91	0.73	0.12	2.21 Di
75308	QZ66- 2Th	5.87	6.09	0.72	0.06	2.10 Th
75230	QZ66- 3Th	5.94	6.06	0.77	0.14	2.93 Th
75233	QZ63	5.97	3.07	0.71	0.05	--
74209	QZ63-.2MM	5.88	2.69	0.67	0.04	0.19 MM
74210	QZ63- 1MM	5.76	2.67	0.66	0.04	1.01 MM
74211	QZ63- 2MM	5.80	2.71	0.68	0.04	2.09 MM
75234	QZ63- 2Th	5.91	3.03	0.81	0.03	2.01 Th
74204	ZQ63-.2MM	2.83	5.62	0.77	0.07	0.20 MM
74205	ZQ63- 1MM	2.90	5.74	0.81	0.06	1.05 MM
74135	ZQ63- 2MM	2.90	5.77	0.70	0.10	2.45 MM

B) WORKABILITY

Alloy No.	Nominal Composition	Hot Short Speed (fpm)	Hot Rolling Range(F) Ingots	Hot Rolling Range(F) Extrusions	Max. Cold Reduction (%)
75231	QZ66	5-7	50	100	---
74206	QZ66-.2MM	6-8	50	100	22
74207	QZ66- 1MM	10-12	50	100	24
74208	QZ66- 2MM	12-15	nil	100	35
75232	QZ66- 2MM	10-12	--	---	--
75235	QZ66- 2Di	8-10	--	---	--
75308	QZ66- 2Th	10-12	--	---	--
75230	QZ66- 3Th	10-12	--	---	---
75233	QZ63	12-15	100	150	--
74209	QZ63-.2MM	10-12	100	150	37
74210	QZ63-1 MM	12-15	100	150	40
74211	QZ63- 2MM	10-12	50	150	45
75234	QZ63- 2Th	20-25	--	---	--
74204	ZQ63-.2MM	6-8	nil	50	22
74205	ZQ63- 1MM	14-16	nil	100	29
74135	ZQ63- 2MM	18-20	nil	100	37

TABLE VII (contd)

Mg-Ag-Zn-Zr+Th and Rare Earths

C) PROPERTIES OF AGED EXTRUSIONS (T5)

Alloy No.	Nominal Composition	Highest Strength * 1000 psi				Lowest Strength* 1000 psi			
		%E	TYS	CYS	TS	%E	TYS	CYS	TS
75231	QZ66	4	49	53	56	--	--	--	--
75232	QZ66-2MM	5	49	55	58	6	45	45	54
75235	QZ66-2Di	5	50	54	56	--	--	--	--
75308	QZ66-2Th	6	50	54	56	6	43	43	54
75233	QZ63	8	45	50	54	11	44	34	55
74211	QZ63-2MM	7	45	49	54	8	40	34	51
75234	QZ63-2Th	8	47	49	55	6	42	35	52
74135	ZQ63-2MM	6	46	47	55	9	42	40	52

*Obtained on laboratory extrusions-T5

D) CORROSION RESISTANCE AND FORMABILITY

Alloy No.	Nominal Composition	Min.Bend* Radius(t)	Corrosion Rate(mcd)*	
			F	T5
75231	QZ66	5-6	3.04	3.42
74206	QZ66-.2MM	5-7	5.3/7	----
74207	QZ66-1MM	4-6	4.30	-----
74208	QZ66-2MM	4-9	3.02	----
75232	QZ66-2MM	5-6	4.48	3.63
75235	QZ66-2Di	4-6	5.27	3.68
75308	QZ66-2Th	4-6	5.53	4.68
75230	QZ66-3Th	5-6	5.41	4.18
75233	QZ63	9-11	4.55	3.53
74209	QZ63-.2MM	4-8	7	----
74210	QZ63-1MM	5-8	5.48	----
74211	QZ63-2MM	6-8	7	----
75234	QZ63-2Th	5-6	5.08	3.78
74204	ZQ63-.2MM	4-7	4.9/7	----
74205	ZQ63-1MM	5-9	4.15	----
74135	ZQ63-2MM	4-9	2.91	----

*Extruded strip (F)

TABLE VIII

Mg-MM-Th-Zn-Zr

A) ANALYSES

Alloy No	Composition	% MM	% Th	% Zn	Soluble %Zr	Insoluble %Zr
74986	ZE41 - 1Th	1.00	1.16	3.93	0.82	0.03
74987	ZE41 - 2Th	0.91	2.18	3.86	0.84	0.03
74984	ZE61 - 2Th	1.00	2.04	5.80	0.81	0.05
74985	ZE61 - 3Th	0.97	3.08	6.02	0.78	0.08

B) WORKABILITY

Alloy No.	Nominal Composition	Hot Short Speed(fpm)	Hot Rolling Range(F) AC	Hot Rolling Range(F) SHT	Max. Cold Reduction(%)
74986	ZE41 - 1Th	5	250	250	55
74987	ZE41 - 2Th	5	200	250	49
74984	ZE61 - 2Th	5	200	200	50
74985	ZE61 - 3Th	7	100	200	48

C) MECHANICAL PROPERTIES

Alloy No.	Nominal Composition	Sheet - H26 %E	Sheet - H26 1000 psi TYS	Sheet - H26 1000 psi CYS	Sheet - H26 1000 psi TS	Extrusions -T5 %E	Extrusions -T5 1000 psi TYS	Extrusions -T5 1000 psi CYS	Extrusions -T5 1000 psi TS
	AZ31	8	36	31	43	--	--	--	--
74986	ZE41-1Th	8	40	40	49	11	53	43	54
74987	ZE41-2Th	6	41	39	49	12	51	41	52
74984	ZE61-2Th	9	41	41	50	10	54	44	55
74985	ZE61-3Th	8	42	42	50	11	50	43	51
	ZK60	-	--	--	--	10	43	41	52

D) FORMABILITY AND CORROSION RESISTANCE

Alloy No.	Nominal Composition	Min. Bend* Radius(*)	Corrosion* Rate(mcd)
74986	ZE41 - 1Th	8	0.52
74987	ZE41 - 2Th	8	4.07
74984	ZE61 - 2Th	8	1.92
74985	ZE61 - 3Th	6	3.41

*Extruded strip (F)

Fig. 1 - Properties of ZK and ZK + A33

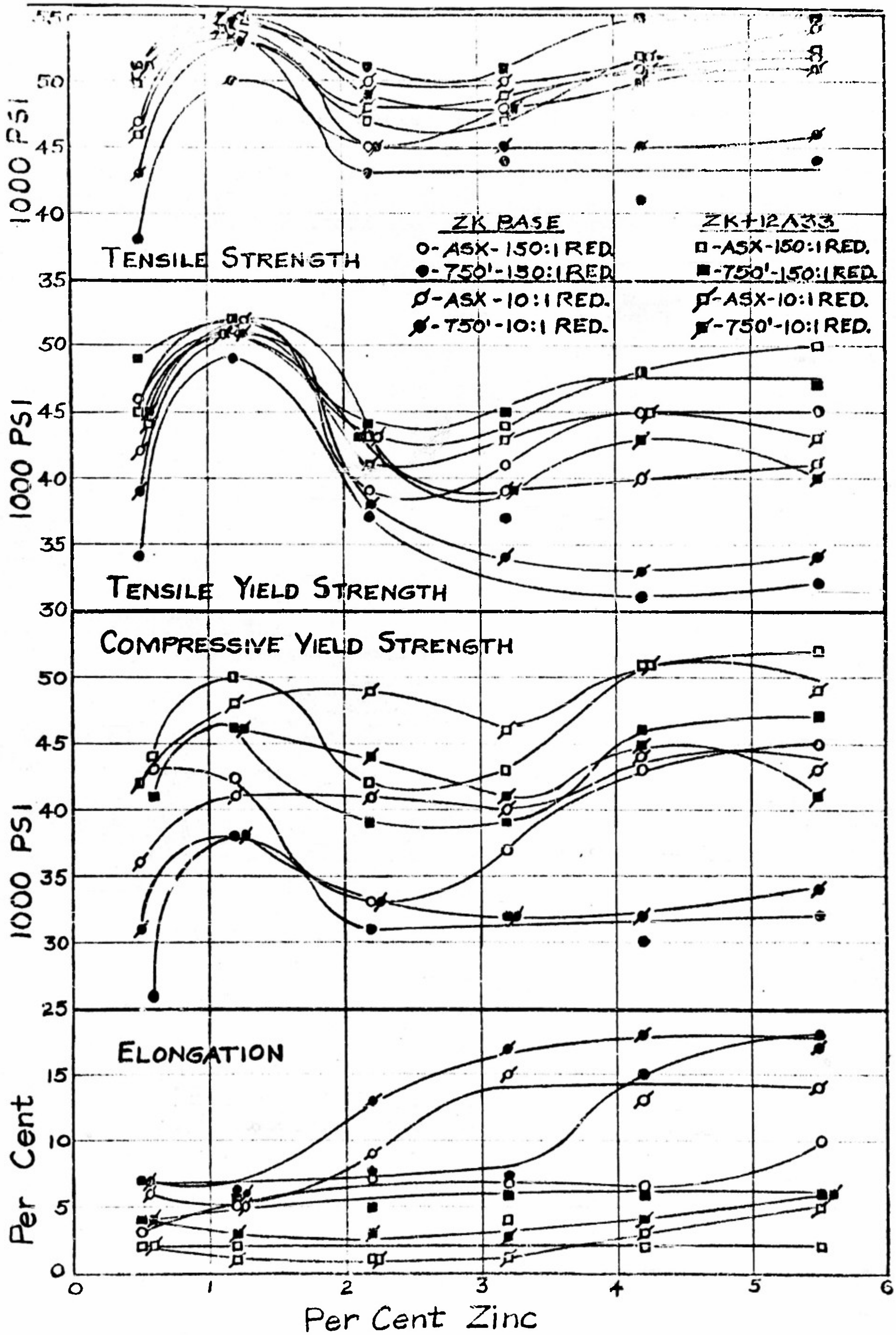
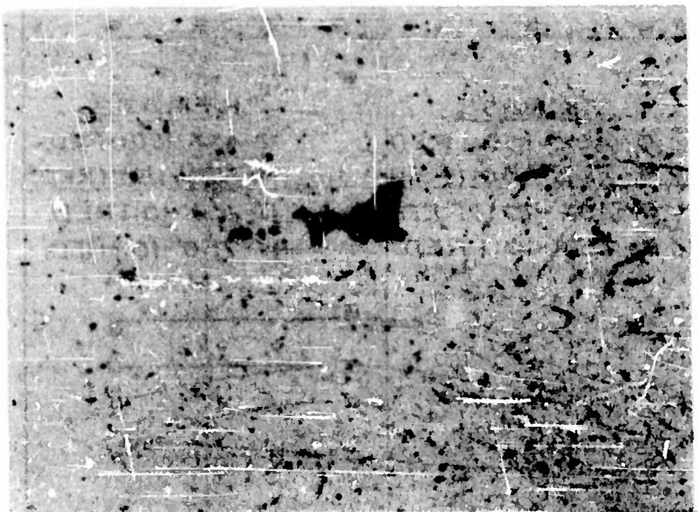


Fig. 2
Microstructure of Mg-Zn-Zr Pellet Extrusions



Neg. 31615
Alloy No. 71422
Etchant-Glycol

1000X
a. ZK00

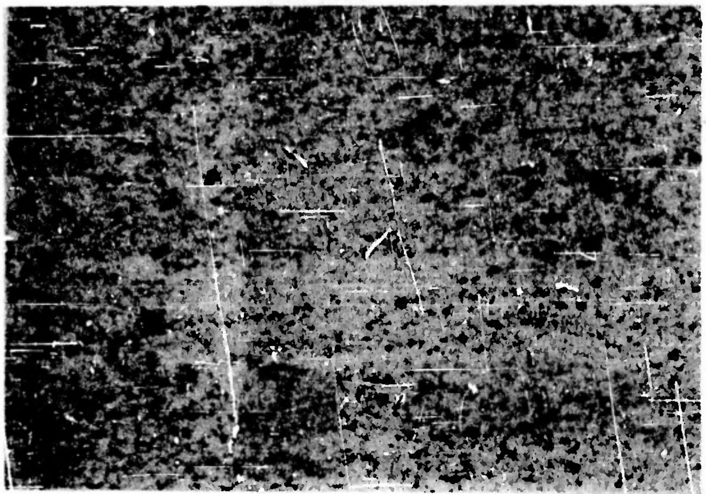
Neg. 31622
Alloy No. 71424
Etchant-Glycol

1000X
b. ZK10

Neg. 31618
Alloy No. 71426
Etchant-Glycol

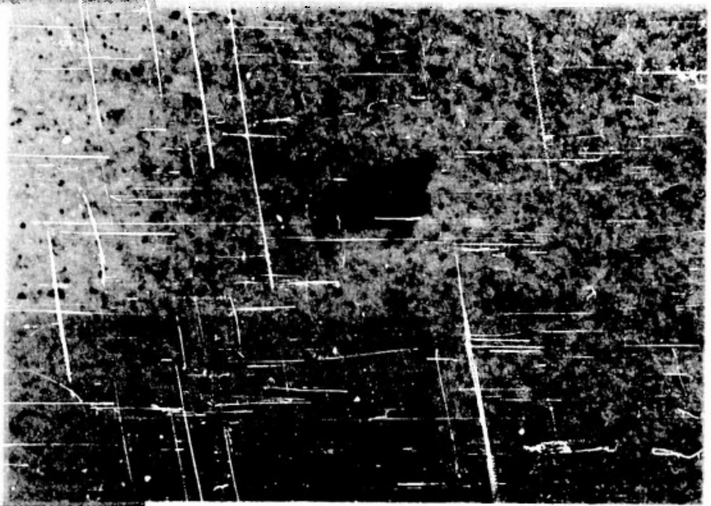
1000X
c. ZK20

Fig. 2 (Continued)
Microstructure of Mg-Zn-Zr Pellet Extrusions



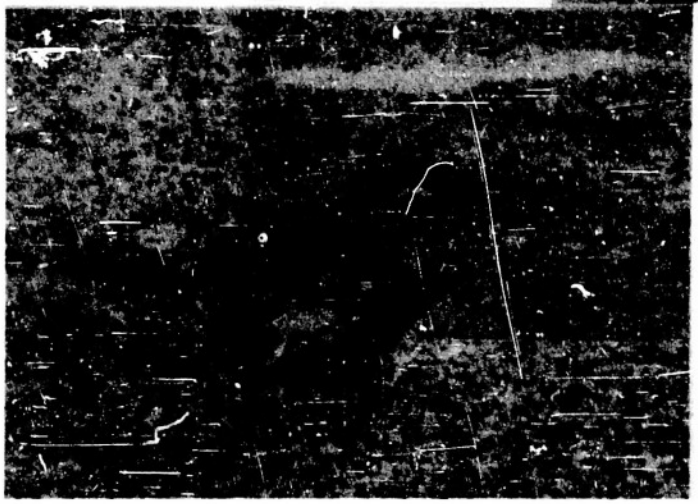
Neg. 31619
Alloy No. 71428
Etchant-Glycol

1000X
d. ZK30



Neg. 31620
Alloy No. 31620
Etchant-Glycol

1000X
e. ZK40

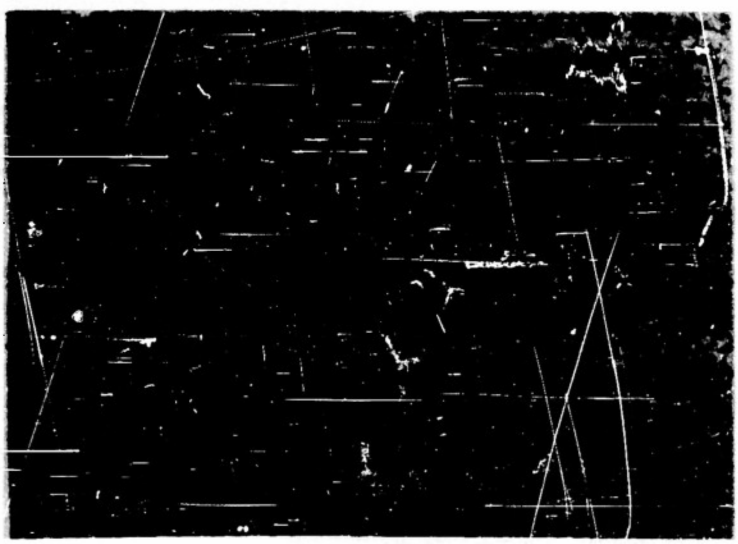


Neg. 31621
Alloy No. 71432
Etchant-Glycol

1000X
f. ZK60

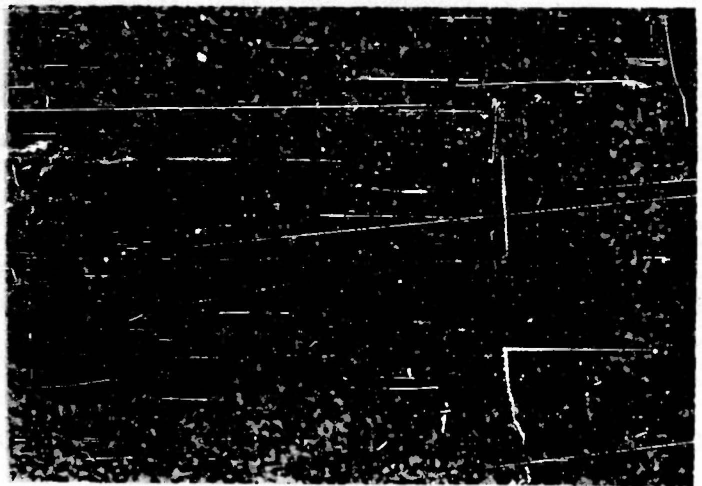
Fig. 3
Effect of Melt Additions on the Microstructure of ZK60 Pellet Extrusions

Neg. 31122 — 1000X
Alloy No. 70615 — a. ZK60
Etchant-Acetic Picral



Neg. 31123 — 1000X
Alloy No. 70960 — b. ZK50-.2Ca
Etchant-Acetic Picral

Fig. 3(Continued)
Effect of Melt Additions on the Microstructure of ZK60 Pellet Extrusions

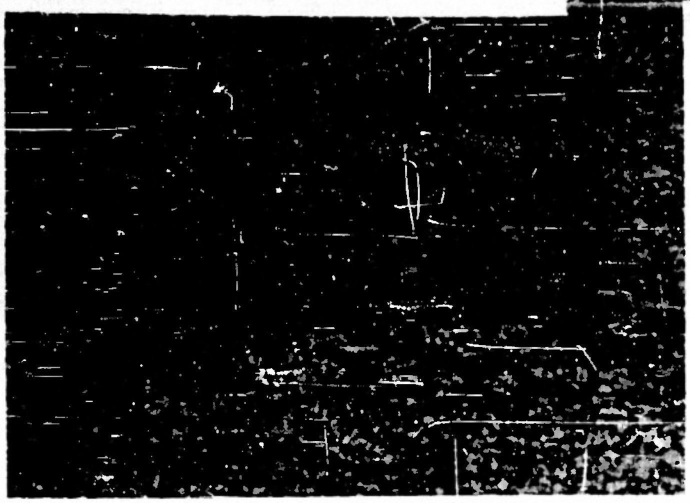


Neg. 31126
Alloy No. 70961
Etchant: Acetic Picral

1000X
c. ZK30-.7MM

Neg. 31127
Alloy No. 70962
Etchant: Acetic Picral

1000X
d. ZK50-1.3Th



Neg. 31128
Alloy No. 70963
Etchant: Acetic Picral

1000X
e. ZK50-.9Ag

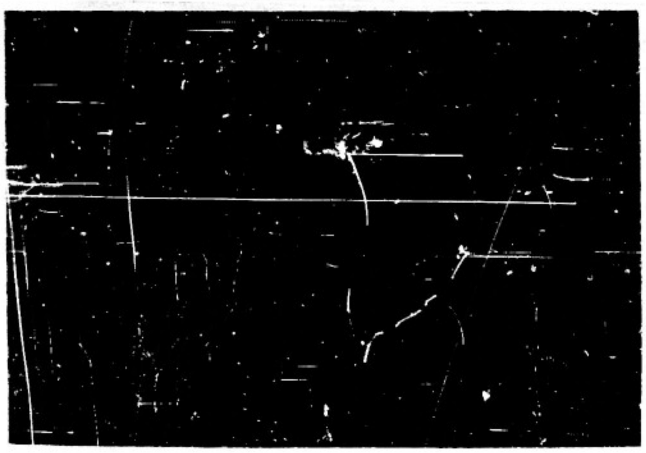
Fig. 4 Plate 1

Cast Microstructure of ZH61 Plus Additions- Ingots

Neg. No. 33169 200X
Alloy No. 73586
Etchant: Glycol
AC

Neg. No. 33170 200X
Alloy No. 73586
Etchant: Glycol
SHT

a) ZH61 Base



Neg. No. 33175 200X
Alloy No. 73444
Etchant: Glycol
AC

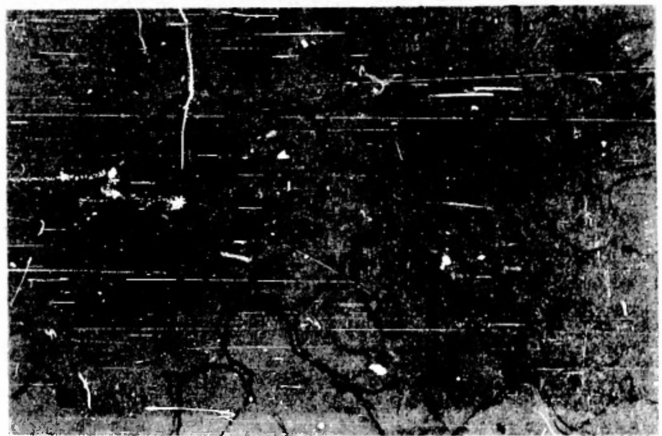
Neg. No. 33176 200X
Alloy No. 73444
Etchant: Glycol
SHT

b) ZH61-0.05 Ca

Fig. 4 Plate 2

Cast Microstructure of ZH61 Plus Additions-Ingots

Neg. No. 33171 200X
Alloy No. 73445
Etchant: Glycol
AC



Neg. No. 33172 200X
Alloy No. 73445
Etchant: Glycol
SHT

c) ZH61-2MM

Neg. No. 33173 200X
Alloy No. 73446
Etchant: Glycol
AC

Neg. No. 33174 200X
Alloy No. 73446
Etchant: Glycol
SHT

d) ZH61-4MM

Fig. 4 Plate 3

Cast Microstructure of ZH61 Plus Additions - Ingots

Neg. No. 33177 200X
Alloy No. 73447
Etchant: Glycol
AC

Neg. No. 33197 200X
Alloy No. 73447
Etchant: Glycol
SHT

e) ZH61-3Ag

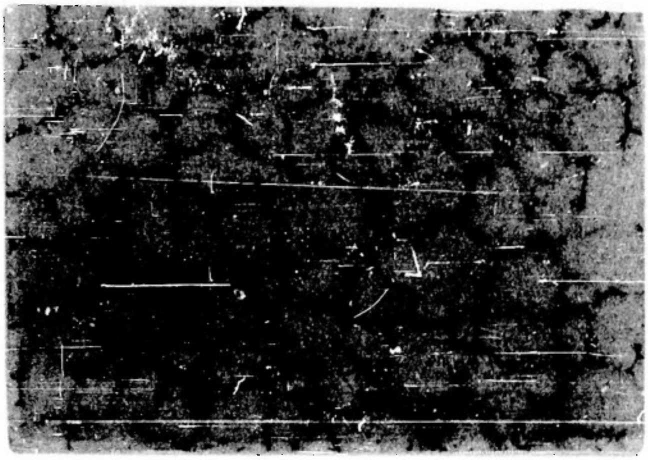
Neg. No. 33195 200X
Alloy No. 73448
Etchant: Glycol
AC

Neg. No. 33196 200X
Alloy No. 73448
Etchant: Glycol
SHT

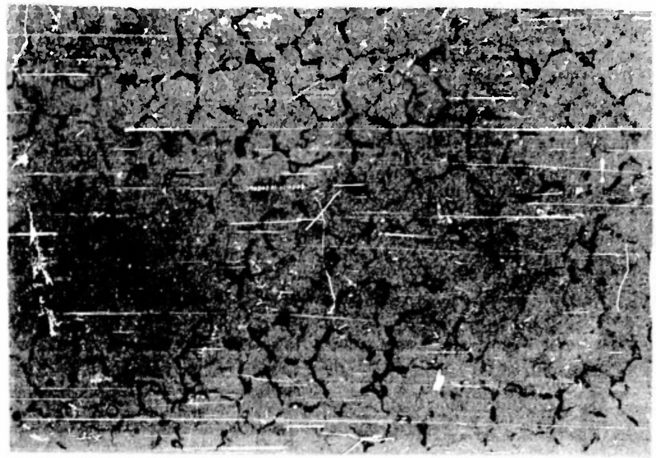
f) ZH61-6Ag

Fig. 4 Plate 4

Cast Microstructure of ZH61 Plus Additions - Ingots



Neg No. 33198 200X
Alloy No. 73449
Etchant: Glycol
AC



Neg. No. 33178 200X
Alloy No. 73449
Etchant: Glycol
SHT

g) ZH61-1 Ba

Neg. No. 33199 200X
Alloy No. 73450
Etchant: Glycol
AC

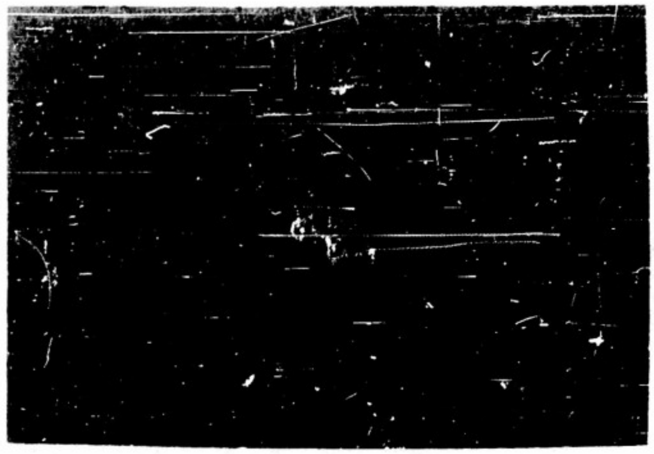
Neg. No. 33200 200X
Alloy No. 73450
Etchant: Glycol
SHT

h) ZH61- 2 Cd

Fig. 4 Plate 5

Cast Microstructure of ZH61 Plus Additions - Ingots

Neg. No. 33193 200X
Alloy No. 73451
Etchant: Glycol
AC



Neg. No. 33194 200X
Alloy No. 73451
Etchant: Glycol
SHT

i) ZH61 - 0.2 Pd

Neg. No. 33201 200X
Alloy No. 73452
Etchant: Glycol
AC

j) ZH61-1 Li

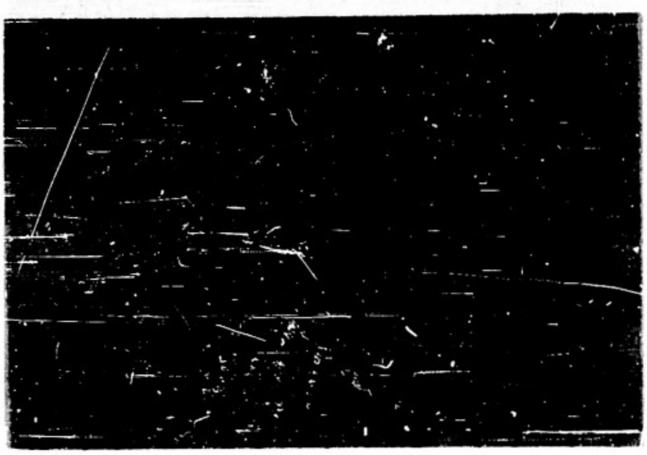
Fig. 4 Plate 6

Cast Microstructure of ZH61 Plus Additions - Ingots

Neg. No. 33202 200X
Alloy No. 73453
Etchant: Glycol
AC

Neg. No. 33203 200X
Alloy No. 73453
Etchant: Glycol
SHT

k) ZH61-0.5 Sr



Neg. No. 33204 200X
Alloy No. 73454
Etchant: Glycol
AC

Neg. No. 33205 200X
Alloy No. 73454
Etchant: Glycol
SHT

l) ZH61 - 2 Cu

Fig. 4 Plate 7

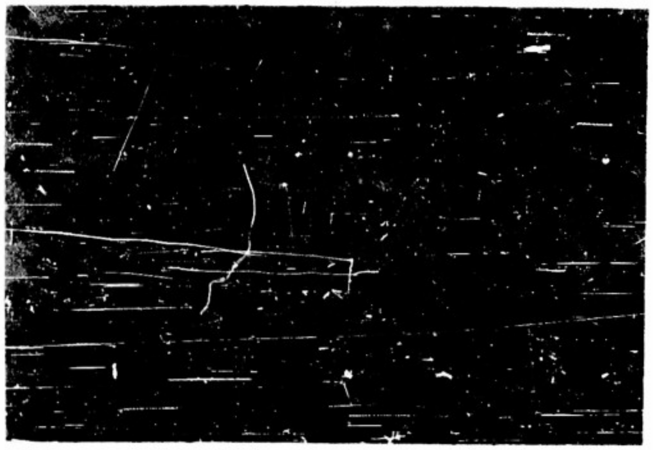
Cast Microstructure of ZH61 Plus Additions - Ingots

Neg. No. 33206 200X
Alloy No. 73455
Etchant: Glycol
AC

Neg. No. 33207 200X
Alloy No. 73455
Etchant: Glycol
SHT

m) ZH61 - 2 Bi

Neg. No. 33208 200X
Alloy No. 73456
Etchant: Glycol
AC



Neg. No. 33209 200X
Alloy No. 73456
Etchant: Glycol
SHT

n) ZH61- 2 Pb

Fig. 4 Plate 8

Cast Microstructure of ZH61 Plus Additions - Ingots

Neg. No. 33210
Alloy No. 73457
Etchant: Glycol
AC

200X

Neg. No. 33211
Alloy No. 73457
Etchant: Glycol
SHT

200X

o) ZH61 - 1 Cr

Neg. No. 33212
Alloy No. 73458
Etchant: Glycol
AC

200X

Neg. No. 33213
Alloy No. 73458
Etchant: Glycol
SHT

200X

p) ZH61 - 2 Hg

Fig. 5

Cast Microstructure of ZH61 Plus Additions - Pellets

Neg. No. 33918 500X
Alloy No. 73844
Etchant: Glycol

a) ZK60

Neg. No. 33914 500X
Alloy No. 73586
Etchant: Glycol

b) ZH61

Neg. No. 33915 500X
Alloy No. 73448
Etchant: Glycol

c) ZH61 - 6 Ag

Neg. No. 33917 500X
Alloy No. 73454
Etchant: Glycol

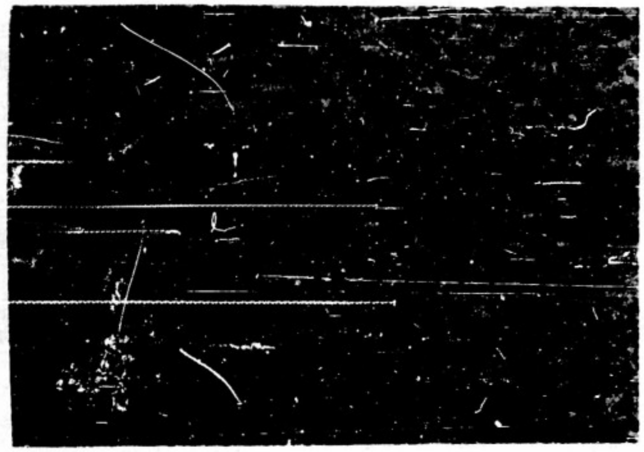
d) ZH61 - 2 Cu

Fig. 6

Microstructure of ZH61 Extrusions Containing Melt Additions

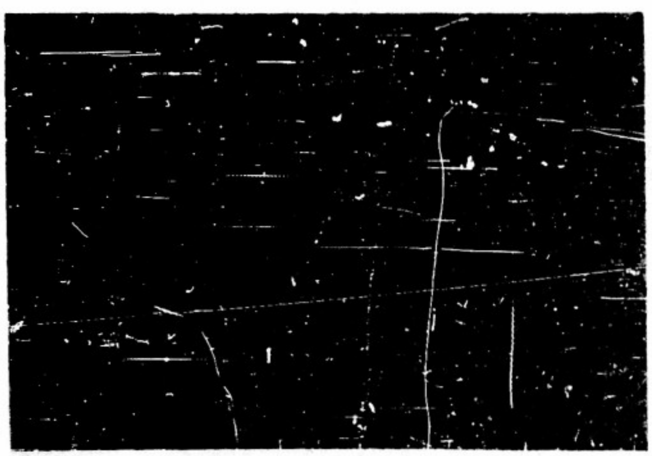
a) ZH61 Base

Neg. No. 33214 500X
Alloy No. 73586
Etchant: Acetic Picral
Ingot

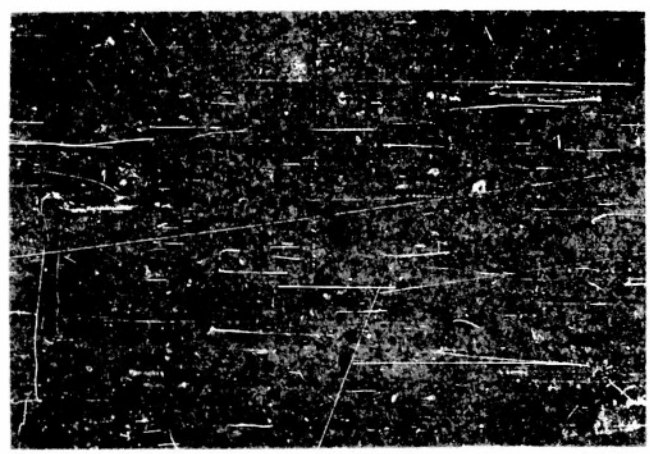


Neg. No. 33215 500X
Alloy No. 73586
Etchant: Acetic Picral
Pellet

Low Reduction Extrusions



Neg. No. 33225 500X
Alloy No. 73586
Etchant: Acetic Picral
Ingot



Neg. No. 33224 500X
Alloy No. 73586
Etchant: Acetic Picral
Pellet

High Reduction Extrusions

Fig. 6 (Contd)

Microstructure of ZH61 Extrusions Containing Melt Additions
b) ZH61- 2 MM

Neg. No. 33216 500X
Alloy No. 73445
Etchant: Acetic Picral
Ingot

Neg. No. 33217 500X
Alloy No. 73445
Etchant: Acetic Picral
Pellet

Low Reduction Extrusions

Neg. No. 33223 500X
Alloy No. 73445
Etchant: Acetic Picral
Ingot

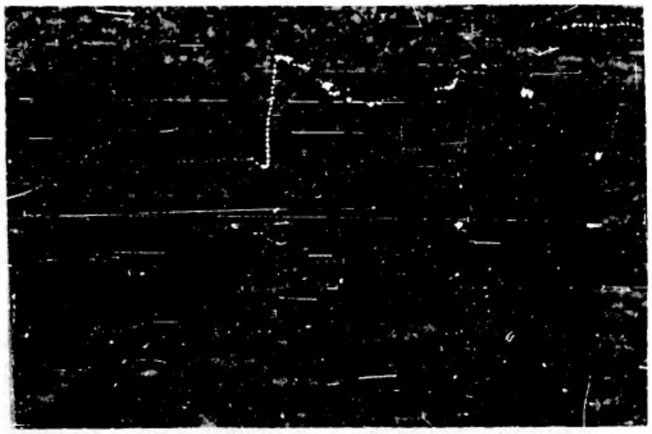
Neg . No. 33222 500X
Alloy No. 73445
Etchant: Acetic Picral
Pellet

High Reduction Extrusions

Fig. 6 (Contd)

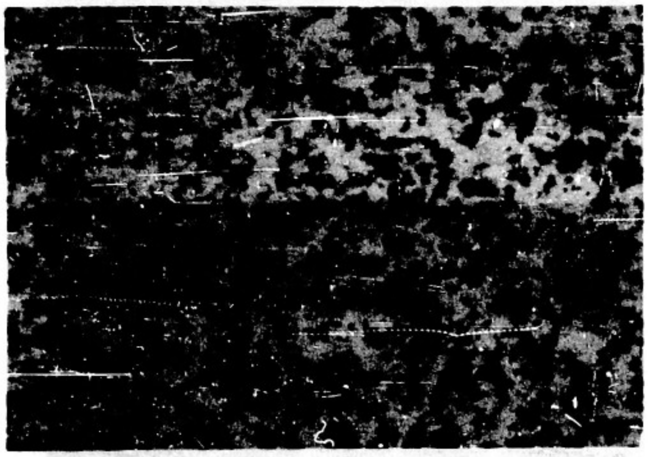
Microstructure of ZH61 Extrusions Containing Melt Additions
c) ZH61-6 Ag

Neg. No. 33218 500X
Alloy No. 73448
Etchant: Acetic Picral
Ingot

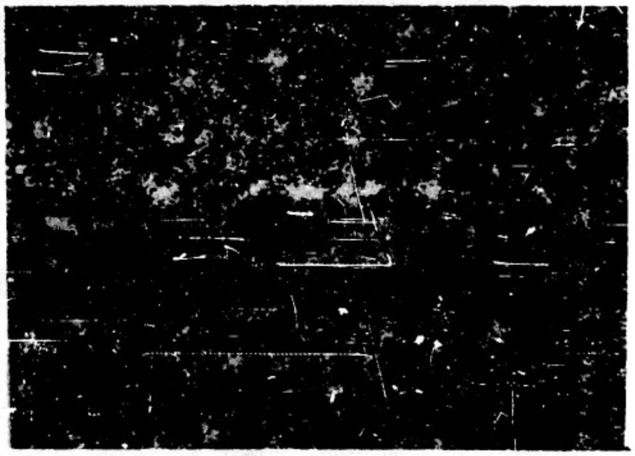


Neg. No. 33219 500X
Alloy No. 73448
Etchant: Acetic Picral
Pellet

Low Reduction Extrusions



Neg. No. 33221 500X
Alloy No. 73448
Etchant: Acetic Picral
Ingot



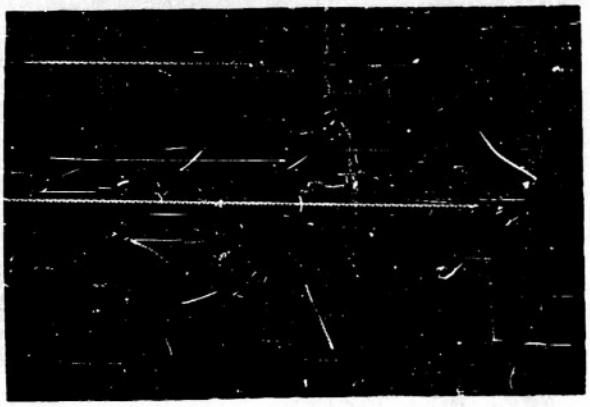
Neg. No. 33220 500X
Alloy No. 73448
Etchant: Acetic Picral
Pellet

High Reduction Extrusions

Fig. 7

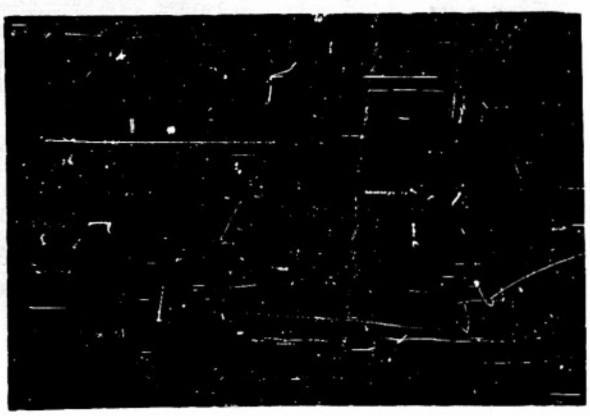
Cast Microstructure of Mg-Ag-MM-Zn-Zr
a) QZ66-MM

AC | SHT




Neg. 33970 Alloy No. 74206 : QZ66 - 0.2 MM Neg. 33973


Neg. 33971 Alloy No. 74207 : QZ66-1 MM Neg. 33974




Neg. 33972 Alloy No. 74208 : QZ66- 2MM Neg. 33975

Etchant: Phospho Picral; Mag. 250X

Fig. 7 (Contd)

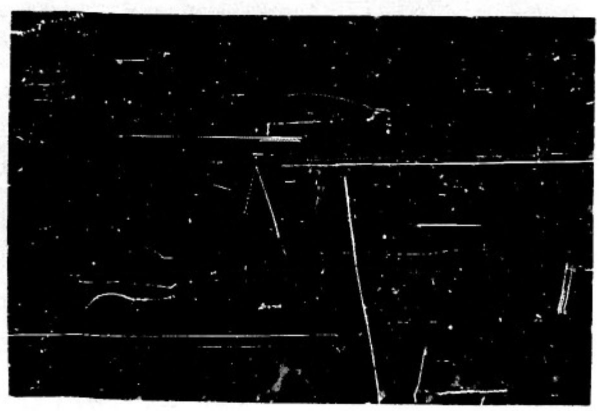
Cast Microstructure of Mg-Ag-MM-Zn-Zr

B) QZ63-MM

AC SHT

Neg. 33976 Alloy No. 74209 : QZ63-0.2 MM Neg. 33979

Neg. 33977 Alloy No. 74210 :QZ63-1MM Neg. 33980



Neg. 33978 Alloy No. 74211 : QZ63-2MM Neg. 33981

Etchant: Phospho Picral Mag. 250X

Fig. 7 (Contd)

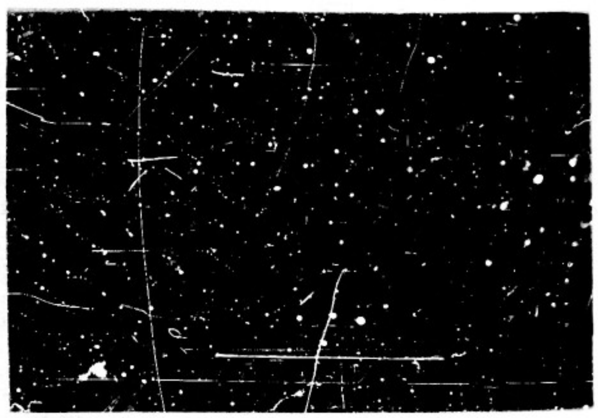
Cast Microstructure of Mg-Ag-MM-Zn-Zr

c) ZQ 63-MM

AC SHT


Neg. 33964 Alloy No. 74204 : QZ63-0.2 MM Neg. 33967


Neg. 33965 Alloy No. 74205 : ZQ63-1MM Neg. 33968

Neg. 33966 Alloy No. 74135 : ZQ 63-2MM Neg. 33969

Etchant: Phospho Picral Mag 250X